A study of conversation participants' choices and connections on the topic of engineering practices and usefulness in day-to-day life

The EP&UDL Study

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Abstract

This paper provides detailed descriptions of the goals, conceptual framing, strategies, research questions, protocols, data analyses, and findings from a study of conversation participants' choices and connections on the topic of engineering practices and usefulness in day-to-day life, the EP&UDL Study. The second of two foundational and exploratory studies in the *Designing Our Tomorrow* (DOT) research program, the EP&UDL Study supported lines of inquiry into STEM education public communication messaging and praxes, specifically as they relate to engineering practices. The study is based on a supposition that conversation hosts' communication choices can support audience participants to generate examples of the usefulness relevance of engineering practices in their lives. The research explored how storytelling and conversation techniques can be used as mechanisms to support caregivers and educators in making connections to engineering practices.

Recognizing that exhibit experiences are often shared through word-of-mouth, this asset-based and co-developed research focused on interpersonal conversations and storytelling about the engineering practices exercised in the DOT exhibits and their usefulness in day-to-day lives. This study involved caregivers and educators in various roles (members of the research team, storytelling ambassadors/conversation hosts, and active audience participants). With a focus on relevance, the study provides early evidence and ideas for practitioners and researchers to design approaches to public communications that help the public perceive the usefulness of engineering practices. For this study, *usefulness relevance* refers to the perception that an object, concept, or activity is of value or utility for achieving personal or community goals. Also emerging from this study are concepts including *personal and local (community) impact range* (Kotkas, et al., 2016), *social and socio-scientific field of focus (*Kotkas et al., 2016)*,* and effective *public communication mandates* (Dervin and Frenette, 2003).

Through a local setting of conversations about engineering practices, conversation hosts were able to support audience member connections to engineering practices. In this paper, words such as 'elicit' are unconventionally used not as a statement of causality, but rather to help describe perceived relationships in the interaction between conversation hosts and active audience participants. A key development from this research was the EP&UDL Model, a local model of conversation participants' choices and connections on the topic of engineering practices and usefulness in day-to-day life, that may help guide ISE practitioners and ISE researchers to foster asset-based public communication about engineering practices.

Introduction

As the earth reaches its carrying capacity for the estimated 10 billion humans that will inhabit it by 2050 (United Nations, 2017), it becomes increasingly urgent to find innovative answers to questions about the world's grand challenges such as those related to sustainable agriculture, transportation, and energy. This can be done by educating and engaging community members, including children and youth, to identify and work toward goals that advance resilience through community engineering practices (Bey et al., 2020; Federal Emergency Management Agency, 2020). Working as communities on collective action is a necessity for addressing the scale of these grand challenges. Informal learning environments, such as science centers, are well positioned to engage community members of different ages through activities that exercise skills and knowledge related to engineering (Ellenbogen et al., 2007; Falk & Dierking, 2019; National Research Council [NRC], 2009), which can provide key practices in collective action.

Informal STEM (science, technology, engineering, and math) education (ISE) campaigns could gain the public's attention, and support communities, in addressing the world's grand challenges. Yet, communication campaign strategies for ISE, while supported by many sources, still need improved community involvement in their development and implementation. Society continues to challenge those who develop campaign messaging for STEM education to move away from primarily top-down perspectives and instead adopt practices that prioritize equity. Bevan (2018) suggested four approaches for advancing equity in STEM—two of which call for shifting STEM-related dominant culture power structures (e.g. the values, practices, and content) from external and expert to embedded and asset-based. In response, the *Designing Our Tomorrow—Mobilizing the Next Generation of Engineers* (DOT) project was developed with a foundation of participatory co-development. The multi-deliverable project funded by the National Science Foundation (NSF, DRL-1811617), acknowledged that culture plays a central role in learning and education (Shagott et al., 2021). By actively valuing broad participation in engineering (Bevan et al., 2018), the project embraced that participants contribute assets and funds of knowledge to engineering education research. For this reason, DOT focused on promoting and strengthening engineering education in a science center environment for girls 9-14 and their families, capitalizing on exhibits as unique family learning environments to foster family participation in engineering. The vision of the project was specific:

> Through culturally responsive co-development and research strategies to include members of Latino communities and provide challenges that highlight the altruistic, creative, personally relevant, and collaborative aspects of engineering, the *Designing*

Our Tomorrow exhibition, called *Creatividad silvestre* | *Wild Creativity*, **showcases engineering as an authentic, everyday activity** for females, and **helps families support each other's engineering proficiencies**. The project provides a theory- and evidence-based framework for creating such exhibit-based engineering challenges.

The DOT project team wanted families to have experiences in which learning about engineering was not an end, but rather a means for achieving their own goals (Bevan, 2018), specifically goals that supported community sustainability and resilience. In other words, families engaging with exhibits would exercise **engineering practices they perceived to be useful for them**.

In addition to co-developing exhibits for the *Creatividad silvestre* | *Wild Creativity* exhibition, the project included two research studies: 1) the study of Collaborative Practices at Interactive Engineering Challenge Exhibits (the C-PIECE study) and 2) the study of conversation participants' choices and connections on the topic of engineering practices and usefulness in day-to-day life (the EP&UDL Study). Both of these studies contribute to larger conversations about theory and practice in engineering education.

The C-PIECE study supported foundational and exploratory lines of inquiry related to engineering practices used by groups engaging with design challenge exhibits (Randol et al., 2023; Shagott et al., 2021)—the culmination of which led to the creation of a framework (the C-PIECE Framework) that includes engineering practices that can be measured in informal settings, informing the development of the 2,000 square foot, traveling, bilingual Spanish/English exhibition, *Creatividad silvestre* | *Wild Creativity* (OMSI, 2023a).

The current paper describes the EP&UDL Study. Grounded in a communication ecology framework and informed by the four mandates of communicative public dialogue from sense-making methodology (Dervin & Frenette, 2003), the asset-based EP&UDL Study embraced the idea that exercising engineering practices could be useful for families to achieve their own goals. In recognition that power dynamics exist between researchers and participants, the OMSI research team approached these relationships with empathy and compassion (OMSI, 2018). Counter to practices in which science center staff and materials sometimes communicate from an expert-oriented, top-down, or unidirectional point of view, the present study was designed to intentionally prioritize the perspectives of community members. As such, the study team recognized that caregivers and their families often make sense of their world by sharing stories with each other (Gottschall, 2012). The team explored ways in which storytelling and conversation, as public communication approaches, supported caregivers in making meaning

about engineering practices that could be exercised at exhibits and the relevance of those practices in their lives.

Through exploratory research of how choices made by caregivers and educators (storytelling ambassadors) as conversation hosts can elicit connections to engineering practices in other caregivers and educators (active audience participants), the EP&UDL Study supports ISE campaigns. The authors of this paper realize that certain liberties are taken when using words such as ‘elicit’, not as a statement of causality, but rather to describe interpretations of perceived relationships in interactions between conversation hosts and active audience participants.

This study focused particularly on the construct of *usefulness relevance*—the perception that an object, concept, or activity is of value or utility for achieving personal or community goals. In this paper usefulness relevance is discussed and measured as *connections*.

The EP&UDL Study involved foundational and exploratory lines of inquiry into communication about engineering practices in which caregivers and educators in the position of storytelling ambassadors hosted conversations as a mechanism to support their audience in making meaning of engineering practices and how they are related to day-to-day life. Some of the documents referenced in this paper used the term 'everyday life’ when discussing things that occur regularly in people's lives. Based on input from the storytelling ambassadors, their interpretation of the term, and their use of it in their stories, the team shifted to using the term ’day-to-day life’, which will be used throughout this paper.

To facilitate discussion about specific roles and actions, the term *OMSI researchers* is used when discussing those people on the research team whose professional experience was related to conducting research; the term *research team* is used when discussing the research team as a whole, which included both storytelling ambassadors and OMSI researchers. Because this research started before the *Creatividad silvestre* | *Wild Creativity* exhibit build was complete, and before the exhibit had a name, research questions, aspirations, and other artifacts from the study referred to the *Creatividad silvestre* | *Wild Creativity* exhibits as DOT exhibits. As such, the two terms are used interchangeably in this paper.

The EP&UDL Study: Planning

Input Gathering and Literature Review

In 2017, when the DOT project was proposed to NSF, the project's second research study was intended to look more deeply at educators' facilitation strategies at engineering design challenge exhibits and build on learnings from the C-PIECE study and the previously funded REVEAL (Researching the Value of Educator Actions on Learning, DRL-1321666) project. When preparing for the second study, four years later, it became apparent that the knowledge and expectations of the research team and the field had changed. Specifically, REVEAL's approach of situating educators as "experts," did not reflect the team's evolving perspective that more fully perceived caregivers (parents/guardians) as "experts," and the belief that they should be positioned as such in the second DOT study.

In 2021 planning began for the second DOT study. With the country, world, and communities all facing changes—struggling in the wake of inequality and racial issues—it was necessary to engage with the project's partners to responsibly update the study's approach.

By engaging with community partners, OMSI project team members, OMSI educators, and the DOT Research Advisory Committee for three rounds of conversations, OMSI researchers 1) expanded ideas about this study, 2) narrowed possibilities, and 3) selected and planned the study's direction. During this time OMSI researchers continued to read relevant literature, note areas for contributing to the field, and reflect on the strengths and constraints of the DOT project resources (e.g. capacity-built through the C-PIECE study, partnerships, personnel, time, budget, and production timeline of DOT prototypes and final exhibits).

Through this process of listening and sharing, it became clear that educators and researchers wanted to work in collaboration with caregivers to help each other understand the connections between engineering practices exercised at exhibits from *Creatividad silvestre* | *Wild Creativity* and the practices caregivers use in their day-to-day lives. In particular, they wanted to help each other understand communications related to the usefulness relevance of engineering practices that support communities to achieve their goals. From this, equity intentions were updated and applied as the study research questions, priorities, methods, and intended contributions were being designed.

Much of the communication about exhibits or engineering is top-down and often fails to support the public in finding the relevance of engineering practices that are exercised at exhibits to practices they use in their own lives. Still, many people hear about exhibit experiences through

word-of-mouth before they even see the exhibit. Museum staff or visitors often talk about a science museum experience in terms of general characteristics (e.g. fun, engaging, and educational), and may be less likely and less prepared to talk about the specific value of an experience. This study spotlights the value of the engineering practices afforded by the *Creatividad silvestre* | *Wild Creativity* exhibits and is positioned to inform situations when visitors or museum professionals have not yet seen the exhibit, but hear about it from someone else who includes the value of the exhibit experience in the conversation.

For this study, members of the target audience of these communications—caregivers and educators—were positioned as researchers and communicators. By leveraging their funds of knowledge, caregivers and educators served as co-researchers and developed conversational narratives that were shared with a proxy audience of other caregivers and educators. Through this process the research identified communication techniques ISE professionals can incorporate into their practice to help elicit connections to engineering practices from their audiences.

Theoretical Concepts

Communication Ecologies

In order to center audience members' voices in communications and create spaces for stories, OMSI researchers saw the need to consider the communication ecology within which community members and the DOT project existed. It was understood that the DOT project was operating within informal STEM education environments that included professionals and visitors associated with the DOT experiences.

To identify malleable factors that could be monitored and manipulated throughout the study, OMSI researchers adopted Foulger's (2004) *Ecological Model of the Communication Process.* This helped guide the study as the model represents the complexity of communication ecologies by illustrating how messages, people, languages, and media interact (Folguer, 2004, A New Model of the Communication Process). Importantly, the model indicates that communication dialogue is reflexive, with message creators becoming "...consumers when they make use of feedback to adapt their messages to message consumers" (Folguer, 2004, A New Model of the Communication Process). It was largely this reflexive component of the model that led to its adoption in the current study, as it aligns with the study's stance that storytelling is not monologue, but part of a conversation that engages people and leads to reflection.

Communication Campaigns

By working with a communication ecology model, the exhibit, *Creatividad silvestre* | *Wild Creativity,* is part of an elaborate and complex campaign, or persuasive communication strategy intended to create social change through education (Hornik, 2013). Communication campaigns for ISE are supported by many sources (e.g. local and federal government, non-profit organizations, research organizations, communication organizations, for-profit companies, traditional educational institutions, and individuals). This support extends to the museum field, which is regarded as one of the most trusted types of media in the United States (American Academy of Arts and Sciences, 2019).

Even when considering the audience, media is often created to convey knowledge of "experts" to the public (Dervin & Frenett, 2003). This method of communication can disregard the experiences of public audience members and fail to understand if the messaging is perceived by the audience as having relevance. This is important because people are more likely to attend to messages with which they can make a connection (Atkins & Freimuth, 2013). Likewise, it is through relevance that people make sense of how information fits into their worldview (Dervin, 2003a).

Brenda Dervin led the development of a theoretical and methodological body of work to guide public communication efforts toward two-way (at least) dialogues between people (e.g. Dervin, 2003b, Agarwal, 2012). Instead of public communication campaigns, she advocated for communicative public communication. Her asset-based approaches were influenced by public advocates such as John Dewey and Paulo Freire (Dervin, 2003c; Agarwal, 2012; Dervin & Foreman-Wernet, 2013). Dervin posits that all humans are actively theory-making and sense-making within their situations; her ecological perspective acknowledges that this is dependent on humans being, doing, and acting in the space and time of real-world situations.

Sense-making

Sense-making is about each person creating, seeking, and using information and theories. As humans exist, sense, and act in the world, they create connections between notions, beings, time, and space. Dervin describes these connections as interpretive bridges (Dervin & Frenette, 2003) that both exert and receive influence from each person's behavior. Dervin explains that communications and conversations energize the behavior of creating connections.

By focusing on communication that allows the audience to voice their own ideas about how they make connections between various aspects in the world, one can better understand how people create, seek, and use information (Dervin, 2003b). According to Dervin, this happens by asking people questions in a way that encourages responses with “verbing terms.” Just as verbs are action words, verbing terms are simply responses that connote action (and probably contain at least one verb). These verbing terms allow both speaker and listener to hear how a person is navigating a world of incomplete information and building bridges to move through real-world, ecological scenarios (Dervin & Frenette, 2003). For example, questions such as, ‘how does it connect to your life?’ or ‘what led to this?’ (Dervin, 2003b) support people to talk about how they are creating interpretive bridges—sense-making (Dervin & Frenette, 2003). Because questions that encourage verbing terms are present in our everyday language, OMSI researchers anticipated such question types would appear in the communication choices used by the storytelling ambassadors to develop rapport and support their audiences in relating engineering practices and processes to their day-to-day lives.

Based on work in the communications field, Dervin and Frenette (2003) assert that people relate to and make sense of the world when communication is not traveling in only one direction. To this end, Dervin developed four mandates that campaigns can adopt for more effective communication: 1) Expert perspectives are not enough; add something to make the campaign messaging appealing to the audience (e.g. include ways the audience might use the information being shared; share human stories; place the information in the context of audience interests), 2) Position the campaign within specific audience social or cultural networks, 3) Integrate audience perspectives (even perspectives that oppose experts), and 4) Be responsive to implications related to social positions such as culture, class, economics, politics, or contradictions from various sources of information (Dervin & Frenette, 2003). The current study used these mandates as an analytical screen when exploring the use of storytelling and conversation as a means of fostering sense-making among communication participants.

Relevance

In Communication

In their overview of theories and practices for communication campaigns, Atkin and Rice specify that messages and campaigns need to be perceived as relevant (2013). Dervin’s work suggests that how people perceive relevance is part of their ongoing sense-making within their ever-changing situations (Dervin & Foreman-Wernet, 2013). Dervin points out that public communication campaigns, even if well-intentioned, often continue to rest on methods that

assume one-way information transmission is effective. Even when campaign designers research audience needs, values, and experiences, they often use the data to deliver yet another conventional information transmission campaign. Dervin advocates for public communication in which organizational communicators and audience members can learn from each other through iterative, responsive communications (Dervin & Foreman-Wernet, 2013).

Messages about engineering in the media often emphasize its connection to math and science skills, overlooking other "vital characteristics of engineering, such as creativity, teamwork, and communication" (National Academy of Engineering [NAE], 2008). As a result, the public takes away the idea that engineering is not "for everyone," while at the same time not being able to clearly articulate what engineers actually do in their day-to-day work (NAE, 2008). With such confusion around the topic, researchers and educators must be deliberate about their communication choices to help ensure that their messaging is believable, appealing, and relevant to the public (NAE, 2008).

In Education

Relevance has been an important construct in science education and studied for decades (e.g. Stuckey et al., 2013), predominantly in the context of formal education (Saracevic, 2007). It has been viewed from multiple perspectives, manifesting in the literature as a variety of socio-psychological constructs, such as interest, importance, and usefulness, to name a few, and often without a clear distinction between them (Stuckey et al., 2013; Priniski et al., 2018).

In an attempt to systematize these constructs, Stuckey et al. (2013) identified three categories of relevance from a broad analysis of the existing literature: personal/individual; vocational/professional; and societal, framing them as having a context of social or scientific. Kotkas et al. (2016) similarly framed choices related to the relevance of content in terms of both impact range, or the level at which people are affected (impersonal, personal, local [community], or global) and the field of focus or context (scientific, socio-scientific, or social). Likewise, Priniski et al. (2018) focused on relevance as "a personally meaningful connection to the individual" (p. 12) with different types of personal meaningfulness: association, usefulness, and identification. Together, these theories provided framing that was congruent with the project intentions—Priniski et al. (2018) supporting the project team's intention that families could exercise engineering practices at the exhibits that are useful in their day-to-day lives, and Kotkas et al. (2016) supporting the project team's intention that families could exercise engineering practices at the exhibit that they could use to achieve goals in their communities.

While the focus on relevance in the EP&UDL Study was largely informed by the work of the Priniski and Kotkas research teams, other researchers' findings beyond these frameworks were congruent. For instance, Westbroek et al. (2005, 2010, as cited in Stuckey et al., 2013) explored factors that promote meaningfulness, and therefore relevance, in the context of formal chemistry education. They argued that science education becomes relevant to students "if the content is embedded in a meaningful context as seen from the students' point of view" and if the learners have an opportunity to "actively participate in the issue at stake" (Westbroek et al., 2005, 2010, as cited in Stuckey et al., 2013, p.10). Multiple studies (e.g. Brown et al, 2015; Harackiewicz et al., 2012; Canning & Harackiewicz, 2015) connect personal usefulness with the concept of utility value (UV), or the extent to which activity is perceived by an individual as useful in reaching their personal goals (Brown et al., 2015). It would reason that similarly, if engineering practices were "embedded in a meaningful context" relevant to visitors, then as informal learners, visitors would likewise have an opportunity to actively incorporate the engineering practices in their worldview and lives.

In the EP&UDL Study

The EP&UDL Study is a study of communication within an education context. While these definitions and understandings of relevance within communication and education literature aligned with the aims of the study, no singular one captured the necessary nuance. As such, the research team drew from these theories and participated in discussions to create an appropriately nuanced term: *usefulness relevance*, the perception that an activity can be used to help achieve personal or community level goals. This term provided language to help articulate that an activity was useful and relevant to accomplishing implicit or explicit goals occurring in a person's day-to-day life.

EP&UDL Study Rationale

Both the Academy of Engineering, through their research for *Changing the Conversation* (NAE, 2008), and the Frameworks Institute, through their research on Effective Narratives in STEM (O'Neil et al., 2014), are public-serving groups working to elevate STEM communication campaigns. Like the field of public communication campaigns, the ISE field is trying to find ways to improve practices and approaches with regard to equity, inclusion, accessibility, diversity, and effectiveness. To this end, vocal professionals acknowledge that both fields have activities and communications that can be too top-down, generated from narrow perspectives, formulaic, and relayed through one-way channels (Bevan et al, 2018; Bales, et al., 2015; Dervin and Foreman-Wernet, 2013).

Out of respect for asset-based approaches, equitable practices, and foundational relationships in communications, and because those who usually create messaging about engineering "rarely reflect the make-up of the target populations of these messages" (NAE, 2008, p. 99), OMSI researchers aspired to apply approaches to communications that were sensitive to power discrepancies; they aspired to adopt practices recommended by researchers advocating that communications promote the public's own sense-making of their world. Congruent with Dervin's notion of creating interpretive bridges, storytelling provides a mechanism for encouraging sense-making among those involved, whether speaking or listening.

As Jonathan Gottschall describes in his book, *The Storytelling Animal* (2012), story allows people to make sense of the world when constantly dealing with incomplete information. The mind is generally uncomfortable with dissonance, uncertainty, and coincidence, and seeks meaning and patterns. In fact, it will often impose meaning—pattern and story are two of the ways that it does this.

When one listens to someone tell a story, they are drawn in because the human mind works with the narrator to anticipate or fill in the details and derive meaning (Cron, 2012; Gottschall, 2012). When a person tells a story, their mind creates, finds, and shares meaning through the telling (Lambert, 2013; MacGuire, 1998). Storytelling has a rich tradition in many communities of color, including Latine culture (Solórzano & Yosso, 2002). While storytelling traditions vary by culture they "may include listening to and recounting oral histories, parables, stories (cuentos) and proverbs (dichos)" (Yosso, 2005). Storytelling is much more than communicating historical information or teaching ethics; it is a tool used by people and cultures to make meaning out of life and generate connections (Solórzano & Yosso, 2002). As such, it was the aim of this research to harness storytelling to help caregivers and educators generate connections to engineering practices.

The current exploratory research was built upon a tapestry of the above literature, woven together to depict a theoretical foundation for the exploration of storytelling, conversation, usefulness relevance, and engineering practices as described in the prior pages. One of the most persistent ideas throughout the literature is that to be effective, a message must be perceived by the audience as relevant to their life. For example, in communication campaigns, success is largely determined by the audience's perceived relevance of the communication (Atkin & Freimuth, 2013). Likewise, Dervin suggests that messages include the point of view of the audience (Dervin & Frenette, 2003), and Gottschall (2012) identifies relevance as a cornerstone of storytelling. Communicating about engineering practices is no different, with

perceived relevance crucial to science education (Stuckey et al., 2013) and the National Academy of Engineering recommending that communication about engineering be of public relevance (2008). In the present study, usefulness relevance is the thread that connects the theoretical backing to the study's ambitions.

The EP&UDL Study: Objective, Questions, and Context

Study Objective

The EP&UDL Study, looked at the storytelling and conversation choices caregivers (i.e. parents and guardians) and educators use to help other caregivers and educators generate connections between the engineering practices exercised at exhibits and their usefulness in families' day-to-day lives. This study centered the voices of caregivers as conversation hosts (storytelling ambassadors) and as active audience participants who participate in conversations and storytelling. **Storytelling ambassadors worked alongside OMSI researchers to develop a conjecture visualization and an evidence-based, local model illustrating relationships between the choices used in communications about engineering practices, such as those one might exercise at the *Creatividad silvestre* | *Wild Creativity* exhibits, and the connections caregivers and educators make to those practices.**

Study Questions

The process for defining this study's research questions was collaborative and iterative. It was driven by intentions for asset-based approaches and inclusion of voices beyond current OMSI research staff. Building on prior research on collaborative practices at interactive engineering challenge exhibits (Randol et al., 2023, 2021b; Shagott et al., 2021), the current study included perspectives from educators, DOT project team members, community education partners (Adelante Mujeres), and researchers in the field (via literature and direct feedback) to determine the questions whose answers would be most useful. While each of the three data collection cycles contributed to the study (see Appendix B and Appendix E for information on Cycles 1 & 2, respectively) and increased the research team's understanding, it was the final cycle, Cycle 3, that represented the overall aspiration and questions of the research (Figure 1).

Practical aspiration
Caregivers [active audience] express the value of an engineering practice at a DOT exhibit BECAUSE the practice is useful in addressing community level challenges in their lives.

Analytical questions
Broadly speaking, the data analysis seeks to help researchers better understand the relationship between choices made through storytelling and conversation about engineering practices and the connections that audience members make to those practices. Specifically, researchers wanted to know:

1. What was expressed by the audience that provides evidence of perceived usefulness relevance (connections) of engineering practices for a community challenge in their lives?
2. What storytelling and conversation choices seemed to contribute to audience expressions that engineering practices have usefulness relevance for a community challenge in their lives?

Figure 1: *Study aspiration and questions for analysis*

Reference Exhibits

The four *Creatividad silvestre* | *Wild Creativity* exhibits that informed the engineering practices used in this study are illustrated in Appendix A. These exhibits were chosen because they are community design challenge activities that afford engineering practices from the C-PIECE Framework (Randol et al., 2023), including those that are commonly found among practices people use in their day-to-day lives to solve problems. Together, the exhibits and engineering practices provided storytelling ambassadors with references around which they would craft their initial stories and conversations.

Storytelling Program

The storytelling program was a practical and integral part of the study. That is, it provided a structured environment wherein the storytelling ambassadors learned about relevant theoretical underpinnings, created and revised narratives, shared their narratives during hosted conversations with active audience participants, and analyzed data. While some aspects of the program (e.g. timeline, overall content) were largely directed by OMSI researchers, many aspects of the program were co-created (e.g. norms, expectations, meeting times and duration).

The program provided a space where storytelling ambassadors felt supported, acknowledged, and responded to—not only as story creators, but theorists, data analysts, and researchers contributing to the interpretation and understanding of the data.

The storytelling ambassador position was key in the project design to support more inclusive and effective ISE campaigns by incorporating all four of Dervin's mandates for better public communications (Dervin & Frenette, 2003). That is, through the storytelling ambassadors, the program included 1) human stories, ways to use engineering practices, and audience interests, 2) shared social and cultural networks as parents, as people interested in science museum activities, and for many, as members of Latine communities, 3) audience perspectives, given that the storytelling ambassadors had shared identities with the active audience members, and 4) was responsive to social positions as aspirations, concept definitions, materials, and processes were co-created among team members in different roles.

The program began in May 2022 and ran through April 2023. The four storytelling ambassadors met a total of 37 times for four hours each with the program lead, who was the lead exhibit developer for *Creatividad silvestre* | *Wild Creativity* and also one of the OMSI researchers. The program schedule was divided into five phases (Figure 2). These included sessions for orientation and planning, three storytelling and data collection cycles, and a phase for final reflection and documentation.

Figure 2: *Storytelling program phases and timeline*

The nine-session orientation and planning phase ran from late May through late July of 2022. During these sessions, the OMSI research team provided an overview of the research study, the exhibit being developed, and the C-PIECE Framework. Storytelling ambassadors visited the exhibit production shop and were able to engage with prototypes of the four exhibit components

used in the study. OMSI researchers introduced the topics of everyday engineering, relevance, and storytelling as central to the study. As a group, the storytelling ambassadors and OMSI researchers came to a consensus regarding the logistics for the upcoming story sessions and characteristics of hosting conversations and good stories. They also co-developed and iteratively refined definitions for key terms that would be used in the research study (Appendices C, F & K).

The EP&UDL Study included three story cycles. Each cycle, the stories had a specific aspiration—a statement of what the team hoped would result from the storytelling and conversation session (e.g. caregivers and educators see that an engineering practice exercised at the *Creatividad silvestre* | *Wild Creativity* exhibit connects to their day-to-day lives). While there were some variations between cycles (see Appendix B and Appendix E, respectively, for process changes during Cycle 1 and Cycle 2), generally speaking, the first three weeks of each cycle were dedicated to storytelling ambassadors revisiting exhibit components; creating, practicing and revising their stories; and documenting their story choices and approaches. This was followed by a Story Day where storytelling ambassadors hosted a conversation with the active audience and shared their stories. The final four sessions of each cycle were used to reflect on the data collected and identify evidence-based recommendations for revisions to the stories. A detailed description of the data review and reflection activities for each cycle can be found in the methods section below.

The final phase of the storytelling program, the Reflection and Documentation phase, lasted four sessions and was used to discuss insights on the data, incorporate themes and reflections into a conjecture visualization—iteratively refined through each cycle, generate ideas for sharing research findings with community members, and finalize the documentation and dissemination plan.

EP&UDL Study Contributors

This research took place in Portland, Oregon, but also included active audience participants living in the San Diego area who were recruited by the Fleet Science Center and who participated via Zoom. The research team included eight persons identifying as either female or male. Four members identified as Latina, two who grew up in the US and two who grew up in Latin American countries (Bolivia and Brazil). Four members of the research team grew up in the United States and identified as White, non-Latino. The academic backgrounds of the team included business, education, policy, and natural, physical, and social sciences. The diverse working roles included caregiver, educator, exhibit developer, insurance claim

assessor, journalist, and researcher. Partners, advisors, and other members of the DOT project team were consulted to obtain input when appropriate and to maintain continuity between this research and other aspects of the DOT project; this included working with a three-member Research Advisory Committee (RAC) with research expertise in museum education, engineering education, and measurement. The RAC provided consultation focused on conducting rigorous, reliable, valid, and culturally responsive research.

Methods

Data from a number of sources were collected over the course of this study. The research process was deeply interwoven with the storytelling program, with each cycle including data collection and analysis that informed subsequent conversation and storytelling strategies used by conversation hosts. Figure 3 provides a graphic of the Story Days' data collection and review that will be discussed in this section.

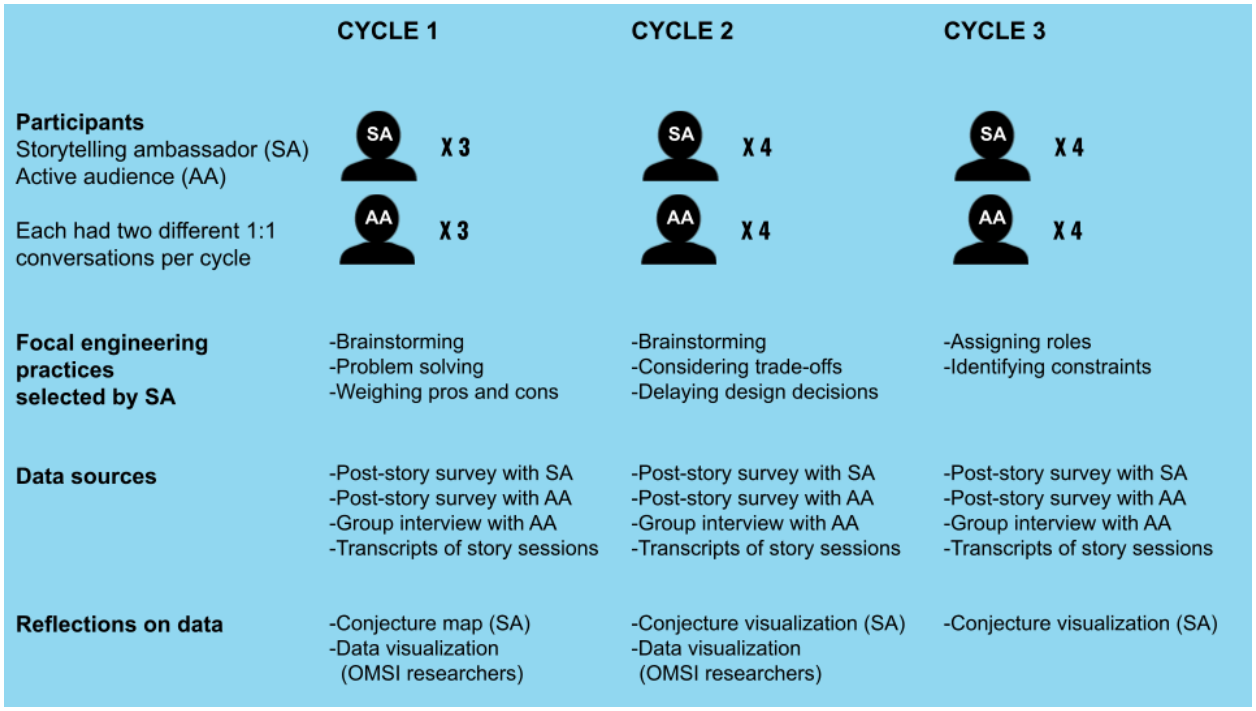

Figure 3. *Graphic overview of the Story Days' data collection and review*

Approaches

To clearly articulate the intended outcomes for the local communication model, OMSI researchers adopted techniques from action research, design-based research, and sense-making methods that would resonate with the research goals, and support collaboration between OMSI researchers, caregivers, and educators who were theorists and whose funds of knowledge enriched processes and outcomes.

Action Research

Action Research (AR) is a research methodology that is focused on promoting democratic change by understanding issues that are significant to participants (Burns, 2015; Stringer, 2014. p. 61). A key feature of AR is the iterative learning cycle that encourages participants to 1) plan, 2) develop or implement their activities, and 3) evaluate the activities (Burns, 2015; Delany & Golding, 2014; Stringer, 2014).

For this study, AR provided a practical frame for both storytelling ambassadors and the OMSI researchers to anchor the constructs of interest in the expertise storytelling ambassadors have when creating and sharing their stories and hosting conversations (Delany & Golding, 2014). This acknowledged the role of the storytelling ambassadors as theorists who reflected on their story content, choices, and dialogue with the active audiences, and prioritized changes based on their experience and understanding from data insights (Delany & Golding, 2014).

Design-based Research

Like Action Research, Design-based Research (DBR) is an approach that supports iterative cycles. DBR consists of three processes (McKenny and Reeves, 2012): 1) exploration, 2) design and construction, and 3) reflection. During these cycles, theories are simultaneously tested and improved leading to refinement of the design and practice (Armstrong et al., 2018).

The inclusion of DBR techniques allowed researchers to observe the ways in which relevance emerged, informing the creation and revision of a conjecture visualization. This visualization served as a connector between the study's theoretical construct of interest (usefulness relevance) and choices made by the storytelling ambassadors in the creation of their narratives. Iteratively refined by incorporating data collected during the cycles, the conjecture visualization was used to inform the development of the local model.

Sense-making Methods

As described in the introduction, Dervin developed a body of work on sense-making that is both theoretical and methodological (e.g. Dervin, 2003b). The researchers decided that while overall project elements aligned with Dervin's mandates, the data analysis could also look for evidence of the mandates within the conversations. The data analysis for this study looked at the type of questions asked by storytelling ambassadors and if they were followed by verbing responses from the active audience participants. The results of this analysis are in the section on content analysis.

To advance theoretical understandings and practical applications through these methodological approaches OMSI researchers collaborated and learned with storytelling ambassadors who integrated each cycle's data and reflections in stories and conversation about engineering practices in day-to-day lives.

Participant Overview

The target audience in this study was adult caregivers of at least one girl aged 9 to 14 and educators, who had either the role of storytelling ambassadors or active audience participants. All participants identified as female.

Storytelling ambassadors were recruited and employed by OMSI. Three of the storytelling ambassadors were hired specifically for this role, while one of the storytelling ambassadors was an educator at OMSI. As mentioned earlier, storytelling ambassadors served as members of the research team for the EP&UDL Study.

OMSI's partnering organization, Fleet Science Center in San Diego, CA, recruited caregivers with girls aged 9 to 14 and educators as active audience participants. To provide variation in the feedback given to the storytelling ambassadors, different active audience participants were recruited each cycle. All active audience participants were provided with a gift card as a token of appreciation for their participation in the study.

Story Creation Overview

At the beginning of each cycle, storytelling ambassadors selected one exhibit component and at least one engineering practice from the C-PIECE Framework to incorporate into a story that would help achieve the aspiration of the cycle. Storytelling ambassadors worked independently

to create their stories, rehearsed with other storytelling ambassadors, received feedback on their stories, and provided comments and suggestions on data collection instruments.

Data Collection

In the Fall of 2022 and Winter of 2023, data were collected through iterative cycles using questionnaires, transcripts of recorded conversations, and transcripts of recorded group interviews; the objective was to document the stories/conversations and the connections the active audience made to the topics. In total, data were collected from 15 individuals: four storytelling ambassadors and 11 active audience participants. All participants provided written informed consent prior to data collection.

Data collection took place during three occasions referred to as Story Days (examples of the data collection instruments are presented in Appendices G, H, and I), each held using the Zoom virtual communication platform. Story Days contained two sessions (each approximately 20 minutes). For each session, there were four breakout rooms containing one OMSI researcher, one storytelling ambassador, and one active audience participant. The storytelling ambassadors hosted a conversation which included sharing a story with an active audience participant and engaging them in conversation around topics from the story. During this time OMSI researchers video-recorded the session and observed, taking unstructured notes to capture impressions, thoughts, and other contextual data that may not be observable from reading a transcript of the session. At the end of each storytelling and conversation session, active audience participants and storytelling ambassadors were given links to 15-minute questionnaires hosted on the Alchemer online survey platform. Once all participants had completed their questionnaires, they changed partners and took part in a second storytelling and conversation session, followed by another post-session questionnaire. After the second post-session questionnaire, two OMSI researchers met with the active audience for a 45-minute group interview. While the group interview was happening, storytelling ambassadors each completed a post-Story Day questionnaire and then met as a group in a private virtual room to debrief. Deviations to this process during Cycle 1 and Cycle 2 are described in Appendix B and E, respectively.

Data Management

Data analysis for each cycle followed a similar process. Each cycle, prior to analysis, file folders were created to store the data from that cycle. Specifically, a file folder was created with the name of the cycle (e.g. Cycle 3). Within that cycle folder, a subfolder was created for each

exhibit component used in a story during the cycle (i.e. garden, kite, workshop, and helmet). In each cycle, the storytelling ambassadors each talked about a different exhibit so the exhibit folder for that cycle corresponded with a storytelling ambassador for that cycle. Likewise, separate subfolders for storytelling ambassador surveys and active audience surveys were made in the exhibit folder. These folders were accessible to only the research team.

Before storing, the data were prepared for analysis. For example, videos from the story sessions and from the active audience group interview were uploaded to otter.ai, a computer program that generated written transcripts of the audio within the videos. A researcher then read through the transcripts for obvious errors, referring to the video recording for clarification and updating the transcript as needed. This document was then saved to the appropriate folder. Data from questionnaires were downloaded from Alchemer. The data from each questionnaire were separated by exhibit, with data for each exhibit saved in a separate file.

Data Analysis

Throughout the process of analyzing the data and documenting findings, the research team strived to be mindful of the words, terms, and preferred language used by the storytelling ambassadors and active audience. It was important that the research stayed grounded in their perspectives and the ways in which they value and make meaning of engineering practices in their lives. The EP&UDL study lead researcher identifies as a bilingual (Spanish and English) Latina female and worked with multiple bilingual project team members to ensure that terms and cultural nuances were adequately interpreted.

Because the research team included the storytelling ambassadors, who did not come to the project with extensive research experience, it was essential that the study used accessible data analysis methods. Content analysis seemed ideal for the task as it is a “... learnable method that precludes the personal authority of the researcher” (Bergetsson, 2016, p.9), and a means of making valid inferences from written text regarding the usefulness of engineering practices from the active audience. A deductive qualitative approach, latent pattern analysis (Kleinheksel et. al, 2020), was used to analyze the written responses from surveys and the transcripts of group interviews and story sessions.

The analysis process was guided by the four stages suggested by Bergetsson (2016): decontextualization, recontextualization, categorization, and compilation. As this research contained iterative cycles in which new information could emerge, the methods deviated from Bergetsson’s suggested process and used a codebook that was refined and updated each

cycle. During the analysis four members of the OMSI research team coded data from the storytelling and conversation sessions of two of the storytelling ambassadors and two members analyzed the active audience group interview transcript to allow for two member check-in of interpretations, coding, and themes from the analysis.

Storytelling Ambassadors' Analysis Overview

As previously mentioned, there were three storytelling cycles, each including a Story Day during which data were collected. The cycles shared many similarities, which will be discussed in this section. Details and variations of Cycles 1 and 2 are discussed in Appendices B and E, respectively.

In the session following data collection, each storytelling ambassador was provided with a copy of the transcripts and responses from both the storytelling ambassador and active audience questionnaires associated with their two story sessions. Additionally, they were given a copy of the active audience group interview transcript.

After reviewing the data, each storytelling ambassador wrote responses to prompts in a reflection matrix, which was refined between Cycle 2 and Cycle 3 (Appendix J). The matrix has two rows, one asking about the choices the storytelling ambassador made when creating their story, including the options considered and the intended goal of the story. The second row contained prompts to provide evidence from the data of when the active audience saw relevance or value in their story, what about their story helped the active audience make connections, and the type of connections the active audience made.

During the following session, storytelling ambassadors used responses from the reflection matrix to create individual conjecture visualizations, presenting and discussing them with the group. Each storytelling ambassador provided recommendations for a meta conjecture visualization—one that incorporated findings across storytelling ambassadors and cycles. The research team discussed the analyses of both the storytelling ambassadors and the OMSI researchers to identify areas of consensus between the analyses of the two teams and introduce interpretations that were unique to either the storytelling ambassadors or the OMSI researchers. To help keep the caregivers' voice centered, the OMSI research team aligned their findings to those of the storytelling ambassadors.

OMSI Researchers' Analysis Overview

Prior to the OMSI researchers' initial data analysis, a codebook was created containing codes, categories and definitions for three types of relevance (association, usefulness, and identification), engineering practices as defined in the C-PIECE framework (type, topic, and implicit/explicit), value, and storytelling ambassadors' choices—including type of conversation opening, invitation, field of focus (scientific, socio-scientific, social), and impact range (impersonal, personal, local [community], global).

To help ensure the initial codes were sufficient and that the coding process was clear, each cycle researchers coded text from the two storytelling and conversation sessions they observed, as well as text from two storytelling and conversation sessions they did not observe. This process allowed the researchers to compare codes and discuss differences, which led to revisions of both the codebook and coding process. These coding comparisons along with comparing the overall analysis of the researchers with that of the storytelling ambassadors helped to support the trustworthiness of the analysis (Lincoln & Guba, 1986). Each storytelling and conversation session transcript was treated as a separate text, as was each question from group interviews and questionnaire responses.

In each cycle, completion of data re-coding and code refinement led to the categorization stage, where each member of the OMSI research team revisited the coded data and created a summary of themes to act as a quick overview of the results. Differences in coding and interpretations were discussed and resolved before continuing to a singular, overall compilation stage. During the compilation stage, the final stage, two OMSI researchers reviewed and summarized the themes, categories and descriptions of the entire dataset from the third cycle—including themes and summaries created by all OMSI researchers.

Trustworthiness

The components of trustworthiness that are relevant to this analysis are credibility and dependability. Credibility regards ways in which trustworthiness can be "increased through getting agreement from co-investigators, from colleagues, from an expert panel or from the informants" (Bengtsson, 2016, p. 13). Dependability refers to "the extent to which data change over time and the alterations made in the researcher's decisions during the analyzing procedure" (Bengtsson, 2016, p. 13). It is suggested that documenting coding decisions and tracking changes is an important part of the process because "re-coding and relabeling are often necessary during the process" (Bengtsson, 2016, p. 13).

This research supported further trustworthiness through the “development of a good coding scheme” (Hsieh & Shannon, 2005, p. 1286). Credibility is enhanced by making sure that “textual evidence is consistent with the interpretation” (Hsieh & Shannon, 2005, p. 1285); a concept that sounds similar to member checking. According to Erlingsson & Brysiewicz (2017, p. 98), “collaborating with others during analysis lets you tap into multiple perspectives and often makes it easier to see variations in the data, thereby enhancing the quality of your results as well as contributing to the rigor of your study.”

Findings

This section primarily focuses on the findings from Cycle 3 of the study. However, to provide context, a brief summary of the findings in Cycles 1 and 2 is included to highlight key findings. A detailed account of data collection and findings from Cycles 1 and 2 can be found in Appendices B and E, respectively.

Story Cycles 1 and 2 Key Findings

In Cycle 1, storytelling ambassadors found that opening stories within a social field of focus with a personal impact range was effective in building rapport with the audience. The ambassadors situated the content of the story in the social and socio-scientific fields of focus, with the impact range including personal and local elements. Aiming to make engineering practices relatable, the content included detailed discussions of engineering practices (e.g. naming them, providing examples of their use in day-to-day life) and personal experiences at a *Creatividad silvestre* | *Wild Creativity* exhibit. Through data analysis and interpretation, storytelling ambassadors refined their understanding of how story and conversation choices could help active audience participants relate engineering practices to day-to-day activities. Additionally, storytelling ambassadors created individual conjecture maps (see Appendix D for the Cycle 1 conjecture map worksheet) and collaborated to create a group version. OMSI researchers developed a *mosaic* (see Appendix B, Figure B1), which confirmed that the Cycle 1 stories primarily engaged audiences on a personal level within the social field of focus.

During Cycle 2, stories leaned more heavily toward the socio-scientific field of focus (and less social) and a local impact range (and less personal), compared to Cycle 1. This shift was supported by storytelling ambassadors' creation of individual and collective conjecture visualizations. These visualizations lead to the storytelling ambassadors co-developing a single

conjecture visualization (Appendix E, Figure E1) that identified characteristics of an effective story and highlighted examples of engineering practices in day-to-day life. Specifically, the visualization illustrated that a story should be personal (include elements of the storytelling ambassador's own life and experiences) and relatable (be familiar to the audience), while providing examples of engineering practices in their lives, with explicit and repeated naming of the exhibit and the practices.

Also during Cycle 2, OMSI researchers analyzed data from the active audience. The analysis suggests that usefulness was the most prominent form of relevance (versus association or identification), with self-generated connections between the audience's life and an engineering practice (Appendix E, Figure E2).

The visualizations and conversations from Cycles 1 and 2 helped the team to identify Cycle 3 research questions and aspirations (Figure 1).

Story Cycle 3 Findings

Storytelling Ambassador Findings

During Cycle 3, the storytelling ambassadors explored how findings from the data might relate to their story choices. Evolving the conjecture visualization based on their review and overall reflections of the Cycle 3 data resulted in their final visualization (Figure 4) containing a three-dimensional pyramid, constructed of blocks representing different elements that storytelling ambassadors and active audience participants bring to a dialogue. The visualization is intended to illustrate that through story and conversation, storytelling ambassadors, as conversation hosts, guide active audience participants up the pyramid, block by block. Based on the audience's interests, experiences, roles, and responses, storytelling ambassadors make storytelling and conversation choices, influencing the path taken up the pyramid. Early in the conversation, the ambassadors contribute more to the conversation (more green and blue blocks); as they ascend the pyramid, the active audience contributes more (red and orange blocks). The dominant impact range of the conversation selected by the ambassador (personal, local, or global) dictates which side of the pyramid they climb, and ultimately influences the connections, or perceived relevance, the active audience expresses within the conversation.

The boxes on the left side of the Cycle 3 visualization (Figure 4) represent the collaborative conversation dynamics between the storytelling ambassadors and the active audience, with an

illustration of the strategies that each brings to the conversation. The diagram illustrates that storytelling ambassadors (labeled as storytellers) bring to the conversation **personal** stories from their own experience, making them **relatable** to the active audience. They use **explicit** language to name and describe the engineering practices to facilitate clarity and understanding. **Repetition** is used strategically to reinforce practices and key points throughout the story.

Similarly, the diagram shows that active audience participants **recognize a familiar situation** involving engineering practices, helping them make sense of the storytelling ambassadors' messages and create connections**.** This allows the active audience to create phrases that reflect the engineering practices and impact ranges (personal or local [community]) back into the conversation. The active audience also **shares insights and stories** about how an engineering practice relates to their day-to-day lives, or more specifically, how they have used or could use the engineering practice in their lives. During this dialogue, active audience participants might also share insights about **feelings of empowerment** through the use of engineering practices or the intention of sharing their insights with their children.

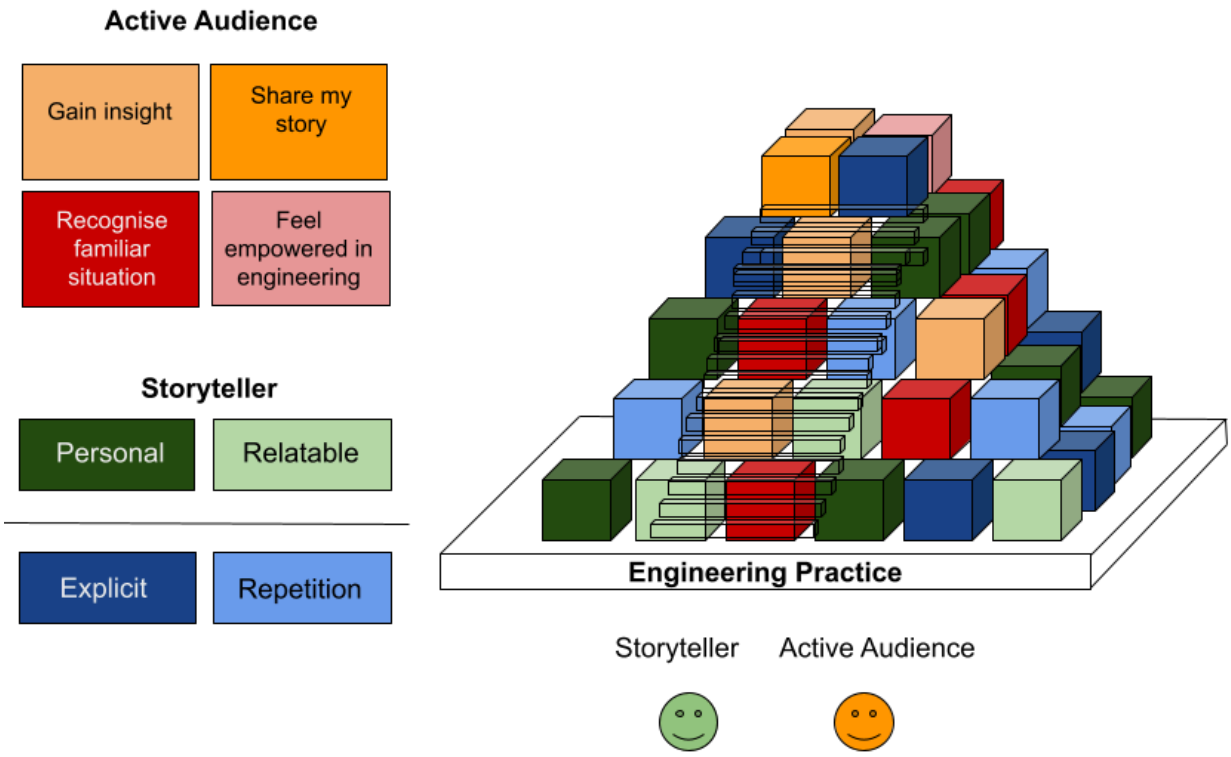

Figure 4. *Storytelling ambassadors' Cycle 3 conjecture visualization*

While the blocks of the pyramid in the visualization are representative of elements brought to the conversation by either the storytelling ambassador or the active audience, the positioning and order are purely illustrative. Because every interaction is different, the elements brought to the conversation and when they are expressed will never be the same.

This collaboratively and iteratively developed conjecture visualization was constructed by the storytelling ambassadors by drawing on multiple sources of information including their lived conversation experiences with the active audience, their written and discussed reflections on the experiences, the transcript records of the conversations, the active audience member questionnaire responses, and the active audience member group interview responses. The active audience member questionnaire and group interview questions focused on identifying storytelling ambassadors' choices/strategies/techniques that helped the active audience participants make connections between the engineering practices and their lives.

While all of the data informed the storytelling ambassadors' conjecture visualization, the active audience input strongly supported aspects of the conjecture visualization that describe what the storytelling ambassadors contributed to the conversation. The evidence of the active audience participants' connections was drawn from the active audience questionnaires, group interview responses, and the transcripts of the conversations. This information strongly influenced the outcomes listed in the conjecture visualization.

In addition, prompted by Dervin's work (Dervin & Frenette, 2003), OMSI researchers realized that the study could benefit from a closer look at how storytelling ambassador questions during the conversations might have been worded in ways to encourage active audience participants to "actively move" into spaces to make sense of the conversation. These findings from the OMSI researchers' analysis are also shared in the section below.

OMSI Researcher Findings

Examples Where Active Audience Participants Expressed Connections to Practices

Data from active audience participants' responses and discussions contain explicit statements about the value of an engineering practice, or a statement connecting a practice to a goal, purpose, or end. As an example, Table 1 provides quotes and the impact ranges of active audience members' expressions of usefulness relevance with regard to the engineering practice, *assigning roles*.

Table 1. *Example expressions from active audience participants at different impact ranges indicating the usefulness relevance of the engineering practice, assigning roles.*

Impact range	Example quote
personal	“first with the kids, teaching them the foundation to have that for the future, to know that it's not going to be themselves having to go through hurdles and obstacles; that you can always have a team and distribute the whole…”
personal	“I was able to understand more when you delegate what people are interested in. It makes the workflow easier and they have interest in doing what you have to do, and then it will save time.”
local (community)	“working together as a community to be able to give back and help maybe a person or family, the family together working together with being able to do that”

Active audience participants described using engineering practices to address familial or interpersonal challenges, develop cooperation strategies, or discover innovative solutions. They also described using engineering practices when resolving commonplace challenges applicable across different areas of their lives. For example, one active audience member described how the engineering practice, assigning roles, connected to social situations:

> ...In my day-to-day life, you have a group or assign tasks to everybody. It is better when it becomes a group, team effort…We do need a community, we do need a group of people to help each other out, to make it a better outcome.

Overall, the active audience reported that engineering practices are exercised across diverse situations, such as school, work, or home. It appears that the use of these practices enables them to confront and resolve simple to complex scenarios in their day-to-day lives. The impact range in which these engineering practices are utilized extends to their local communities.

Examples Where Storyteller Ambassadors Used Field of Focus and Impact Range

In addition to exploring how usefulness relevance emerged in the active audience data, OMSI researchers were interested in how active audience expressions of engineering practices’ usefulness relevance for their community were related to the storytelling ambassadors’ choices. Data from Story Day session transcripts suggest that overwhelmingly, the field of focus

throughout the stories and conversations was socio-scientific—an intentional strategy manifested as explicit statements about the storytelling ambassadors' own connections to engineering practices. However, a social field of focus was used in the opening of the story to build rapport with the active audience. Local (community) impact range was used to elicit connections to the audience's communities.

Data from both the storytelling ambassadors and the active audience participants highlighted the intricate ways in which active audience participants' perceived usefulness relevance of engineering practices corresponded to different conversation and storytelling choices. Guided by Kotkas et al. (2016), storytelling ambassadors incorporated choices related to field of focus and impact range into various aspects of the story and audience interactions. Through this process, storytelling ambassadors found that active audience participants made connections to engineering practices—especially those pertaining to relational matters such as with family members or their community.

Table 2 contains excerpts from transcripts that help to illustrate storytelling ambassador choices. As the storytelling ambassadors overwhelmingly chose to use a socio-scientific field of focus, all excerpts in Table 1 reflect this field of focus and reference engineering practices (e.g. drawing from prior experience, assigning roles, identifying constraints) with regard to day-to-day life. The impact range—the level of day-to-day life, in a particular example, affected by the use of an engineering practice—chosen by storytelling ambassadors varied between personal (engineering practice involved audience participants or their close family and friends) or local (engineering practice involved audience participant’s community). Examples are provided in Table 2

Table 2. *Examples of storytelling ambassadors' choices of engineering practice and impact range*

Impact range	Excerpt from storytelling ambassador (engineering practice in *italics*)
personal	"When faced with challenges, whether they be big or small, do you find it beneficial to *draw from prior experience*?"
personal	"...was assigned a role by my grandmother. And I often thought that she did this randomly. And undoubtedly she sometimes did. ...But looking back before *assigning someone to a specific role*, she really did take our strengths, interests, ages and skills into consideration."
personal	"Do you do that [*identify roles*] at home with your children, like, Hey, you're gonna fold the towels and you're gonna put up the dishes, or you're gonna put up the toys?"
local (community)	"I'm wondering if you can think of a challenge that one of your communities has? And then do you think *identifying constraints* would be helpful in engineering or coming up with a solution?"
local (community)	"And so, do you have any other examples, whether it's in the community or outside of the community, of *identifying roles* and its value?"

Examples where storytelling ambassadors used questions

In addition to choices related to field of focus and impact range, storytelling ambassadors made choices in terms of the type of questions they used. In this regard, as started earlier, Dervin (2003b) suggests that some questions can elicit verbing responses that shed light on how people are making sense of their situation. Verbs are meaningful because sense-making is an active, ongoing process involving many different types of constructive actions. As storytelling ambassadors shared their stories, they used questions through the opening, story content and invitation, as well as during their dialog with the active audience.

Table 3 provides illustrations of some question types that storytelling ambassadors used to encourage active sense-making during their conversations with active audience participants. Two types of questions seem to align with Dervin's assertions about eliciting verbing responses (2003b)—questions that supported active audience participants to formulate how engineering practices might be useful for helping them 1) navigate within their lives, and 2) achieve desired results in their lives.

Table 3. *Examples of questions used by storytelling ambassadors*

Question type	Sample questions (and segment of conversation)
Questions that supported active audience participants to formulate how engineering practices might be useful for helping them *navigate within their lives*	"And what value do you find in this engineering practice? Because assigning roles is an engineering practice." (during invitation segment) "First of all, how do you feel about all this? And how do you feel about dress codes, attires? (during invitation segment) "How do you feel that maybe you could bring this [assigning roles (engineering practice)] out into your day to day outside of the home? (during dialogue segment)
Questions that supported active audience participants to formulate how engineering practices might be useful for helping them *achieve desired results in their lives*	"How would somebody with low vision try to walk around our neighborhood?" (during content segment) "What do you do to help you in assigning those roles?" (during dialogue segment)

Examples of Mandates for More Effective Public Communication in Conversations

Storytelling ambassadors and active audience participants engaged in conversations that promoted effective communication and supported the audience to actively make connections to the engineering practices described by the storytelling ambassadors. Through these conversations, Dervin's four mandates for creating communicative public communications (Dervin & Frenette, 2003) were used as a path to move from the one-way communication and expert driven communication campaigns to a dialogue between people. The following excerpts provide illustrations of how Dervin's four mandates were present in the storytelling sessions.

1) Add something more than just the expert perspective in the campaign messaging to possibly make it more appealing to the audience. In the following excerpts, the storytelling ambassadors and active audience members make the topic more appealing by sharing human stories and ways to use engineering practices.

Ways that storytelling ambassadors kept the active audience engaged in the dialogue

> *active audience:* "Oh, definitely, definitely. My girls are already older to where now I give them more chores as opposed to me handling everything. So we get done faster and out of the house if you need to. So yeah, definitely assigning things to different people gets the job done quicker and just efficiently."
>
> *storytelling ambassador: "*And what value do you find in this engineering practice? Because assigning roles is an engineering practice."
>
> *active audience:* "Absolutely. I mean, for their future for when you know, they have their own kids or they have to deal with an event …. assign roles to anybody for everybody, you know, have everybody do a part of their own and collaboration and get everything done, …definitely, it will work for the future for them, and to build just more, you know, structure for them."

Ways that storytelling ambassadors invited the active audience into the dialogue

> *storytelling ambassador:* "I agree. 100%. I, my daughter, is very careful with my dishes. And I love my tableware. So I trust her with the dishes. And I wouldn't trust my boy doing the dishes. Because of him, I know that he wouldn't be happy doing it. And then you know what happens after that. On the other hand, my husband is very handy. So he's in charge

of something that breaks, something's not going running smoothly in the home. He's in charge of taking care of that. Yes, my boy likes being organized. ….So I think it's funny how we can implement this engineering practice. And that's what we're doing really in the home. And then we can go outside of the home and do it there as well. So we're kind of taking what we do into the home, taking it out into our community and then vice versa. So do you think that the community benefits from this from assigning roles? I think we've talked about it a little bit, but how do you feel the community is benefiting from it?"

active audience: "Yeah, I feel the community is really benefiting from this kind of approach, engineering practice, like, it makes a community to develop, you see, maybe there are some things we need to do jointly. And some people have passion for it, and they like to do it. By the time you tell them, Oh, this is for your own sake to do, and they do it effortlessly. It's to make everything work and function correctly."

storytelling ambassador: "Right, it'll run smoothly, just like us in the home. It's running smoothly, it's getting done. Everyone feels you know, I think chores, nobody's happy to do them, which is okay. But it's getting done. And the person who's doing it is comfortable in that position, and doing it. So, well, I think that you have, you have just as much experience, if not more. I've learned from you."

active audience: "We all learn every day. And I did learn from you really."

2) Situate the campaign within specific audience social or cultural networks. The storytelling ambassador in the following excerpt, situates the content of her story and the engineering practice in her life with respect to her cultural and personal background as a way to not only appeal to the active audience, but to offer a concrete illustration of the engineering practice and from it, support the active audience in connecting to it.

storytelling ambassador: "So today I'm going to talk to you about an engineering practice that is valuable not only in your home but also in your community. And I'll start by mentioning that like many Latin American families mine is a massive one, big. My grandparents' home was always a Grand Central Station of sorts. It was always welcoming aunts and neighbors and cousins and compadres. Sunday cookouts were and still are a time to come together and dance and laugh and eat and wow, the amount of food that was and still is made is always a sight to behold. Most food was prepped on

Saturdays all seasoned and simmered to perfection by various family members. Everyone had a role."

active audience:: "...Like in my place of work. For example. Yeah. For you not to get overwhelmed and ensuring that your time management is well utilized. You just have to have team work and delegate to make sure the task is done appropriately and on time."

3) Include audience perspectives. This principle was observed when storytelling ambassadors and active audience participants engaged in a dialogue that included sharing their own perspectives, connections, and questions.

Ways that storytelling ambassadors invited the active audience to share perspectives

storytelling ambassador: "But once I explained the three sisters or the milpa rule to her, her score at the garden improved. And then we went back and forth trying to see who could be who because you know, that's how we do it. So pulling from prior knowledge and showing my daughter this scenario. So she could take this notion with her when approaching other tasks and challenges. It has value. So I'm hoping she'll keep this in mind when approaching other things. So there's value in approaching challenges with either using past experience in mind. And there's also usefulness in identifying strengths and assigning roles, like the three sisters or the milpas. So, tell me, when faced with challenges, whether they be big or small, do you find it beneficial to draw from prior experience?"

active audience: "Yes, when you know of the situation, yes. So it really does help out because you already have experience and you already kind of know what to do and what not to do. Yeah, that really does help. And they'll help you as well when you're doing something else and it went wrong, or it didn't go the way it was supposed to now you know that you shouldn't do it that way or find a different solution."

storytelling ambassador: "that's an engineering practice drawing from prior experience. And then also, like you said, learning, what kind of went right or wrong and kind of tweaking that. That's an engineering practice as well. And so what about identifying roles? This is an engineering approach. It's a tool that is very useful in being a part of a community or a community challenge. Do you see any value in this and when I speak of a community, it can be as small as your immediate family, or your neighborhood or your

church or the school or you'd maybe like an online community that you're part of. And we're talking about identifying roles."

*active audience. "*Yes, just having help and when you need it, or when you are stuck, and you can get ideas from somebody else, something that you wouldn't think, you wouldn't think of. I feel like more minds working together, it's better because not everybody thinks, nobody thinks the same. And you probably wouldn't have thought of that, as somebody else did, or vice versa."

Ways that storytelling ambassadors invited the active audience to share ideas

storytelling ambassador: "Yeah, you hit the nail on the head. That's exactly right. And again, identifying roles and learning what a strong suit of a person is, and saying, Hey, I know you're good at this, what are your ideas on this, because it can kind of help and inspire me to do better in this role. That's an engineering practice. And so as you can tell, that's what we're kind of talking about is engineering, engineering practices that we've been using them, you know, every day, it's not the same thing as just like, you know, constructing a building, you know, what most people think that is about, it's much more than that. And so we're trying to bring and show that you are using engineering practices every day, you use them in different scenarios, and to kind of keep that up and empower the young ones to, you know, to embellish that. And so, do you have any other examples, whether it's in the community or outside of the community, of identifying roles and its value? And its value? Do you do that at home with your children, like, Hey, you're gonna fold the towels and you're gonna put up the dishes, or you're gonna put up the toys?"

active audience: "Yes, they really enjoy trying to help me cook. So different roles in that, and one will mix and one will try to crack the eggs, and I will try to take out the egg shells. And, yeah, we do that a lot when it comes to cooking, and they just really enjoy that one of my daughters is in a cooking class, because she really likes it. Flour tortillas yesterday, homemade flour tortillas, I think, maybe, she could teach me now."

4) Be responsive to implications related to social positions; accept that campaign goals are contextual and be responsive. This mandate involves a focus on how structures, social class, and constructs are often defined and explained by experts. In this regard, the third cycle provides an example of responsiveness with regard to the construct of community. Through the storytelling program sessions, the storytelling ambassadors were very vocal with the OMSI researchers about how the notion of community is very personal. The OMSI researchers were

responsive to the storytelling ambassadors and the storytelling ambassadors were responsive to the active audience members.

Example of community defined by one storytelling ambassador

> *storytelling ambassador*. “So, when we do, we walk around our neighborhood. A problem or challenge we have is that our sidewalks in the neighborhood have cracks, or they lift in places....it can be really expensive to fix a sidewalk, you know, or people might not be able to trim back bushes or physically clean sidewalks. So we tried to put ourselves in different people's shoes, and identify some of these constraints our neighbors might have in solving or engineering a solution to our sidewalk and walking around a neighborhood safely.”

Example of community defined by one active audience participant

> *active audience.* “I do see a lot of challenges with, like after school programs and putting the kids into something fun and something entertaining for them to be able to communicate, and get their schoolwork done, and really get to know the community as well. And then the kids in their community. I see a lot of challenges also, with homelessness and wanting to help out in that area, and how expensive everything is right now. And everybody that's struggling in homelessness and finding ways to dig themselves out, when they're already in a hole, working together as a community to be able to give back and help maybe a person or family, the family together working together with being able to do that.”

Discussion

To understand how the data connect to the practice and research of STEM public communications, the findings are discussed in terms of the supposition upon which this entire study was created—conversation hosts' communication choices can support audience participants to generate examples of the usefulness relevance of engineering practices in their lives. As such, this section first describes how the data from both conversation hosts (storytelling ambassadors) and active audience participants address the study’s final research questions and aspiration. The section then presents the EP&UDL Model, a local model of conversation participants’ choices and connections on the topic of engineering practices and usefulness in day-to-day life. Following the description of the model, the section provides reflections on the study limitations, a description of the contributions to knowledge for

researchers and practitioners, and possible future research questions. During the discussion of the findings, the term ‘elicit’ is used counter to the suggestion of causality often ascribed, to instead describe perceptions of relationships between the conversation hosts and active audience participants as they co-create their conversation.

Interpreting the Data Through Analytical Questions

The findings section of this paper described three data sources that can be used for empirical information—the conjecture visualization created by the storytelling ambassadors, the conversation transcripts, and the analysis of questions and mandates conducted by OMSI researchers. Data without context is meaningless. Without a point of reference there is nothing tethering the data to the world and thus no way to interpret or make sense of it. To that end, the context of this study is framed by the aspiration and analytical research questions that guided the third story cycle (Figure 1).

A commonality between the questions and the aspiration involves active audience participants making connections to engineering practices—specifically those afforded by *Creatividad silvestre* | *Wild Creativity* exhibits. For this reason, it seems practical to first discuss how expressions from active audience participants support the study’s ambition and then discuss conversation host choices.

What Connections Were Expressed by the Active Audience?

By participating in storytelling and conversation with the storytelling ambassadors’, active audience participants *recognized and returned* that engineering practices were the focal point of the conversation. Through the process, the research team observed that the engineering practices and impact ranges (personal or local) used by active audience participants appeared to correspond to those used by the conversation hosts. Likewise, active audience participants took part in *sharing insights*, as they provided their own examples of usefulness of engineering practices in day-to-day contexts that demonstrated a socio-scientific field of focus and at times expressed perceptions of empowerment related to engineering practices.

What Choices Did Hosts Contribute?

As conversation hosts in this exploratory study, storytelling ambassadors utilized various conversation components to help elicit connections from active audience participants. For example, by *opening* with a question or a statement, storytelling ambassadors engaged active audience participants from the beginning of the interaction. Through carefully choosing language that *illustrates the topic* in their own lives, storytelling ambassadors shared their experience with the topic in their own lives, creating an opportunity for active audience participants to make a connection to similar situations in their lives.

Storytelling ambassadors incorporated multiple communication strategies throughout their conversations. To create an atmosphere of comfort and to encourage trust, the stories that started the conversations were intentionally personal, containing details of the storyteller's lives. Likewise, to promote connections to engineering practices, stories were created to be relatable to the audience. To endeavor for clarity, the topic of conversation was explicitly stated and described using examples from the storytelling ambassadors' own life. Storytelling ambassadors repeated the engineering practices, increasing the likelihood of the active audience participants incorporating them into their own examples.

At the end of each story, storytelling ambassadors incorporated an *invitation,* transforming the story from an expression of their life, to the context of a conversation. Through the use of specific types of questions (questions about how engineering practices might connect to helpful and desired outcomes), conversation hosts could influence the way in which active audience participants responded.

In this study, storytelling ambassadors found that including story elements with a personal impact range was important in building rapport with active audience participants. The study further found that the incorporation of field of focus and impact range into stories seemed to influence the responses elicited from active audience participants. Choices that included a socio-scientific field of focus and a local (community) level impact range appeared to be related to connections from active audience participants regarding engineering practices with active audience participants describing their use of engineering practices with their communities as a means to address day-to-day life challenges. Specifically, the engineering practices mentioned by the conversations hosts: making a plan, considering trade-offs, brainstorming ideas, and assigning roles.

The storytelling ambassadors utilized choices in their stories to create a context for a

conversation with the active audience. These stories acted as vehicles for the conversation hosts to build rapport and initiate a conversation around a public communication topic—engineering practices exercised at exhibits are useful for accomplishing day-to-day goals, including community related goals. Although the storytelling ambassadors initiated the conversations, the experiences were co-created with the active audience participants. Information flowed bi-directionally, with storytelling ambassadors and active audience participants toggling between storytelling and story receiving. As such, storytelling ambassadors did not communicate the relevance of engineering practices to active audience participants, rather they hosted conversations in which active audience participants generated their own connections.

These conversations supported active audience participants in making meaning and perceiving usefulness of engineering practices. This act of hosting conversations, transformed the communication of the STEM campaign messaging around engineering from the traditional one-way, expert-driven delivery of information to messaging that was targeted, co-created, relevant, audience-informed, and contextual, highlighting recommendations from communication theorists (e.g. Dervin & Frenette, 2003; NEA, 2008). In fact, strategies called out as important by the conversation hosts (i.e. personal, relatable, explicit, repeated), have also been called out by other researchers as typically important for communication campaigns (Atkin & Rice, 2013).

Bringing it All Together

Establishing how data addressed the research questions and aspiration is a preface to illustrating how the findings of this study might have practical applications. Since this study is grounded in sense-making and usefulness relevance, it seems appropriate for the findings to be articulated in a manner that supports the reader in making meaning of the study's findings. To do this, findings from this study have been incorporated into a local model of conversation participants' choices and connections on the topic of Engineering Practices and Usefulness in Day-to-day Life, aptly named the EP&UDL Model (Figure 5*)*. The EP&UDL Model is a distillation of the findings grounded in the study's theoretical framings using the format of the Ecological Model of the Communication Process (Foulger, 2004).

Specifically, the EP&UDL Model positions Story Days within a communication ecology congruent with the project's sociocultural approaches. It acknowledges the communication that occurs around designed environments, but decenters the common notion of "education," and its

associated power differentials. That is, conversation hosts do not teach, they initiate conversations to provide situations where participants self-generate connections to the topic in their own lives. This allows active work to center audience participant voices in the processes of communication, with continual re-framing in the context of real-world environments. Specifically, the model situates storytelling ambassadors as conversation hosts (they initiate, or host, the conversation) within an asset-based context.

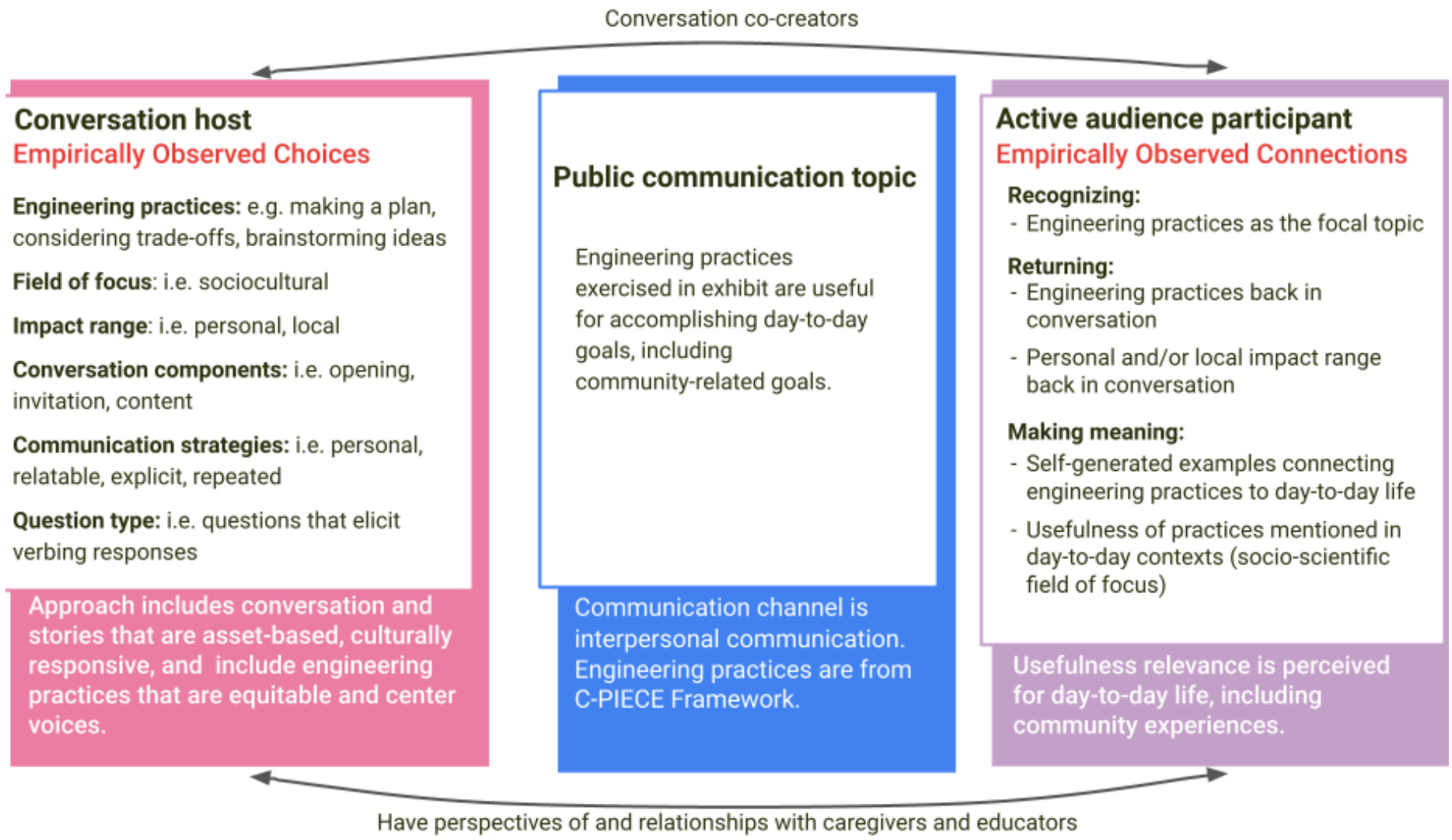

Figure 5. The local model of conversation participants' choices and connections on the topic of Engineering Practices and Usefulness in Day-to-day Life (*EP&UDL Model)*

The box on the left of the EP&UDL Model aligns with Foulger's (2004) structure with those people who initiate the messaging. In the EP&UDL Model, it represents the conversation host/storytelling ambassador and contains choices the conversation hosts identified as important when trying to support audience connections to engineering practices: fields of focus, impact ranges, conversation components, communication strategies, and question types. The bottom of the box lists some of the key approaches used to design the study, the Storyteller Program, and the Story Days.

The center box represents the public communication topic, *"Engineering practices exercised in exhibit are useful for accomplishing day-to-day goals, including community-related goals."* This borrows from Foulger's (2004) construct of *messages*. The bottom of this box explicitly states that the communication channel in this campaign is interpersonal and that the focal engineering practices in the campaign come from the C-PIECE Framework (Randol, S. et al, 2023).

The box on the right aligns with Foulger's (2004) structure with those people from the public communication audiences—in this study this is the active audience participant (named to acknowledge that they are actively sense-making) and illustrates the connections active audience participants made during conversations. The bottom of the box refers to the theoretical interest in the active audience members' perceived usefulness relevance of engineering practices in day-to-day life and community experiences.

Connecting the conversation host (left box) and the active audience participant (right box) are bidirectional arrows. The bottom arrow, borrowed from an aspect of Foulger's (2004) model that illustrates there are perceptions and relationships that message initiators and message audiences have about one another, shows the shared perspectives of and relationships with caregiver and/or educator. The top arrow, inspired by aspects of Foulger's (2004) model indicates that public audiences become message co-creators when providing responses. When Dervin's four mandates for communicative public communication were used as a data analysis lens, researchers identified evidence for each of the four mandates. These bidirectional arrows reflect the mandates. That is, the bottom arrow reflects the shared interests and networks of the conversation participants. The top arrow reflects the incorporation of audience perspectives and the responsiveness to those perspectives.

To enhance the flow and clarity of this paper, additional information on preceding steps in the EP&UDL Model's development—specifically the theoretical contributions to each model component—have been placed in Appendix L.

Considerations of the Study Design's Limitations

Research Intent and Process

One of the intentions of this research was to study approaches to public communications that do not follow prior formulas and power discrepancies and instead follow practices recommended by researchers advocating that communications promote the public's own sense-making of their world. In order to satisfy this intention, the direction of the study was continuously and collaboratively evolving with the input of multiple key perspectives. However, because conversations with many different groups informed the Storytelling Program, this malleability may have created some fuzziness in terms of what was being asked of the study participants at different stages of the process. This study was exploratory, yet utilized words that could connote causality (e.g. elicit), to illustrate perceptions of possible relationships between storytelling ambassadors and active audience participants during their interactions. This may have caused some dissonance or confusion for some readers.

Methods Used

As with all research, this study required the research team to prioritize the study's components to satisfy financial and temporal constraints of the DOT project. While the components were streamlined in a thoughtful and educated manner, certain choices could have eventually impacted the results. For example, the sample size was relatively small—four storytelling ambassadors and 11 active audience participants all from large metropolitan areas in the West Coast region of the United States (Oregon and California). Both storytelling ambassadors and active audience participants were a relatively homogenous group, with most identifying as Latina women of the same generation. In addition, while we are confident in our methods and findings, we acknowledge that storytelling ambassadors and active audience participants were placed in a scenario which was contrived. Therefore, the communication between the participants observed in a different context may vary from that seen in this study. Additionally, while the storytelling ambassadors were part of the research team, data from their storytelling sessions were coded and analyzed, making them in some ways a "quasi-participant." This dual role may have potentially impacted the study in unknown ways.

The active audience participants were recruited from the pool of caregivers who had participated in programming at the Fleet Science Center, as well as from Fleet education staff, which suggests they may have been more familiar with engineering design principles and concepts than an individual without that background. In addition, while this research attempted

to be mindful of the unique situation in which storytelling ambassadors and active audience participants were placed, it is possible that having the sessions recorded may have influenced both the depth and the length of the participants' interactions and the feedback provided by the active audience.

Contributions to Knowledge

As this exploratory research built upon the engineering practices in the C-PIECE Framework (Randol, et al., 2023), it has utility for ISE practitioners, providing them with early evidence and ideas for designing approaches to public communications that elicit perceptions of usefulness relevance of the engineering practices. At the same time, this research provides a local foundation upon which other researchers can build, expand and explore the concept of usefulness relevance in engineering education communication.

This research pursued foundational and exploratory lines of inquiry into using storytelling and conversation as mechanisms for caregivers and educators to communicate about engineering practices with other caregivers and educators. This allowed the storytelling caregivers and educators, both conversation hosts and active audience participants, to share knowledge about engineering practices with each other. By observing shifts in audience responses coinciding with choices made in their stories (e.g impact range and field of focus), conversation hosts were able to alter how they described their own experiences using engineering practices in their lives, thus providing active audience participants a context in which they could make connections to engineering practices exercised at the engineering exhibit.

This study is intended to be part of the larger body of research and knowledge in the ISE field about approaches for promoting engineering learning through asset-based, inclusive processes. This study enriched the field for ISE practitioners and researchers by defining and developing the EP&UDL Model—a local model of conversation participants' choices and connections on the topic of engineering practices and usefulness in day-to-day life (Figure 5). This research was conducted in a context with leadership, collaboration, and participation from members of Latine communities, still uncommon in the field of ISE in the United States, a rarity that accentuates the value of affirming prior findings and generating new findings. In the course of researching and developing the EP&UDL Model, this study affirmed and generated evidence for concepts that will benefit ISE practitioners and researchers.

In light of this, the position of this project has been that engineering practices are a means to accomplish personal or community goals. As such, the ISE field as a whole could benefit by adopting a perspective that engineering practices have usefulness relevance for generating community solutions. Likewise, informal learning environments could benefit by collaborating with communities to find out what is relevant to them and co-develop programming to meet community needs or interests.

To this end, public communications in informal education should discuss engineering practices with active audiences in ways that support them in making connections to the topic. For example, web engineers and exhibit developers could use images and copy that help people connect engineering practices to activities in their day-to-day lives. To be more effective, professionals could collaborate or conduct usage testing with members of the target audience to ensure that visitors are making connections to the content. Educators could adopt the role of conversation host, creating opportunities for learners to co-create the conversation and generate meaning and connections to engineering practices. Principal investigators and researchers could seek opportunities to better understand ways in which the field can engage with individuals and communities such that they support the development of self-generated schemas around engineering practices.

For practitioners, this research provides at least three contributions (Figure 6):

1. This research affirms two-way conversation involving story sharing as an asset-based approach that yields sense-making and can be considered in engineering-related communication campaigns when working with ISE practitioners and female caregivers from Latine communities.
2. This research positions the usefulness relevance of engineering practices as important for caregivers in science center active audiences because it supports engineering, not as an end, but as a means for achieving their goals. This positioning supports approaches to equity in the ISE field (Bevan, 2018).
3. This research generated early evidence of choices that ISE practitioners can make in their communications to increase the likelihood of active audience participants perceiving engineering practices as usefully relevant in their lives, including in their communities.

In this paper, we have talked about the roles of practitioners involved with this study—media developer, exhibit developer, and educator. Influenced by this research, the media developer and the educator incorporated learnings from this study by facilitating communications about engineering practices such that audiences might generate their own connections to practices.

For example, the media developer worked with the storytelling ambassadors to create personal stories about engineering practices for *Creatividad silvestre* | *Wild Creativity* web communications. The educator expanded approaches for communicating with families to mention practices from the C-PIECE Framework in the context of an anecdote that might elicit connections related to the practices. For instance, if an educator notices a family interacting with materials at a design challenge exhibit, the educator might say something like, “Are you enjoying gathering materials for your design? When I get home tonight, I am going to gather materials to make dinner.”

For researchers, this study provides at least three contributions (Figure 6):

1. This research demonstrates that relevance can be studied as a more specifically qualified construct, called *usefulness relevance*, that we expect supports perceptions of engineering, not as an end, but as a means for people to achieve their goals.
2. This research describes relationships between constructs in a peer-hosted communication ecology about engineering practices. That is, using the constructs *field of focus* and *impact range* in communication choices can influence perceived usefulness relevance of engineering practices among active audience participants. For example, how field of focus and impact range choices are included in a conversation or story, can influence social and community connections—and expressions—among active audiences.
3. This research offers the local model of conversation participants’ choices and connections on the topic of engineering practices and usefulness in day-to-day life—**the EP&UDL Model** (Figure 5)—as a guide for subsequent studies of relationships between practitioners (e.g. exhibit developer, media developer, educator, facilitator) and active audience participants, to study how communication choices in conversations and story-sharing about engineering practices relate to perceived connections between the engineering practices and active audience participants.

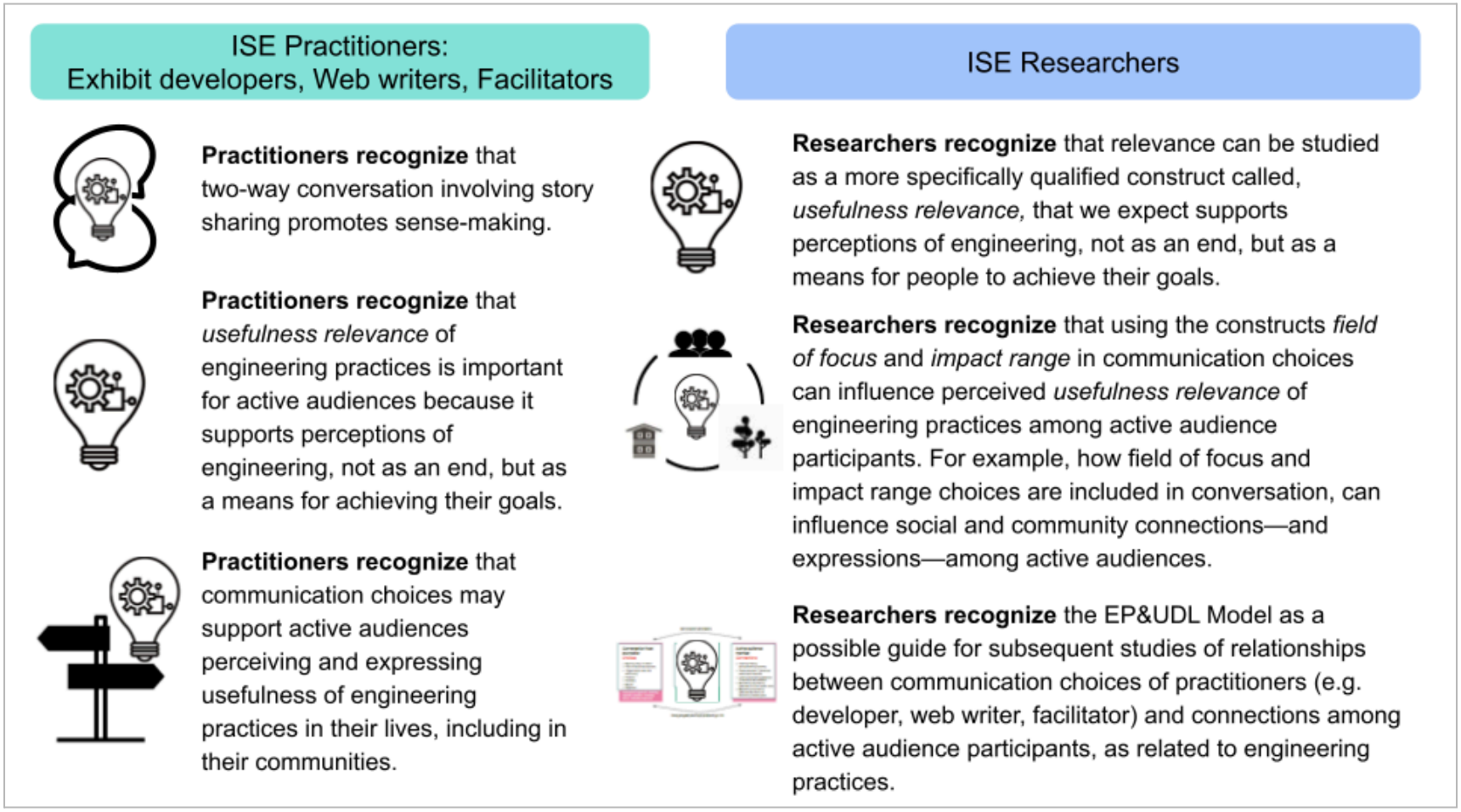

Figure 6. *The contributions of early evidence from the EP&UDL Study to ISE practitioners and ISE researchers*

Researchers reading this paper will appreciate that this study drew on multiple areas of prior work to create new perspectives on relevance. The study drew on research literature from the fields of communication campaigns, formal STEM education, informal engineering education, and storytelling. Equally important, if not more, the study drew on unique contributions from practitioners who shared current questions they have about their work, and contributions from members of public communities, particularly Latine communities, who shared their personal and cultural assets about engineering practices in day-to-day lives throughout the conversations and stories.

Based on these inputs, the members of the EP&UDL Study team stitched together key concepts—engineering practices, field of focus, impact range, and usefulness relevance—into a study design that generated evidence suggesting positions of and influences between variables within an ecological, interpersonal communication model. The intent for studying and situating these variables into a local model is to provide early evidence- and theory-based foundations that are unique and have promise for informing future research and practices on communications about engineering practices.

The variables and the EP&UDL Model presented here can be used for design and development research. For example, as organizations such as the government, learning organizations, and public communication groups strive for broader participation in engineering, approaches and findings from this study can inform tests on how communication choices, such as field of focus and impact range, influence ways the public makes connections to engineering practices. Design and development research could also investigate how the EP&UDL Study findings and model could be applied by educators and facilitators on the museum floor.

Likewise, the variables and EP&UDL Model presented here can be used for additional foundational research. Through the course of this study, this research team became interested in relationships beyond the scope of the study. For instance, researchers realized they could continue to study the usefulness relevance of engineering practices in relation to not just the personal and local (community) levels of impact range, but also the global level. The researchers also see reason for future research to pay particular attention to the importance of social relationships in the usefulness relevance of engineering practices. That is, researchers noticed that active audience participants often described the utility and relevance of engineering practices because they practices were useful or relevant to members of their family or community. This suggests that perceived relevance could be highly influenced by social factors and relationships—an important factor to consider when attempting to elicit usefulness

relevance. While the STEM communication landscape commonly promotes engineering as a career or an identity (NRC, 2008), perhaps more communications could be about how engineering practices are useful for people and communities to achieve their goals, even elaborating on Brown et al.'s (2015) concept of community utility value. Another possible line of inquiry could explore whether the approaches, evidence, and model presented in this study are applicable in content domains outside of engineering practices.

Informal STEM education campaigns have the potential to make constructive contributions to their communities—perhaps the world—by adopting communication practices that gain the public's attention and support communities in addressing grand challenges. There is an opportunity for informal engineering education to leverage its diverse sources of support (e.g. government, corporations, community-based organizations, research groups, communication firms, educational institutions, and individuals) to develop and refine ways to involve the community in the development and implementation of campaign messaging. This was exemplified by the prioritization of equity and engineering for a sustainable future by the *Designing our Tomorrow* project.

Moving forward, communication campaigns that support members of the public to self-generate examples of engineering practices as useful for achieving their goals will benefit individuals and communities. This particular study involved active audience members who had not yet seen the *Creatividad silvestre* | *Wild creativity* exhibit, but were part of conversations about the engineering practices exercised in the exhibit and their usefulness in day-to-day lives. Perceptions that engineering practices are useful for community goals are important to nurture given that sustainable futures rely on community level goals. Conversation and stories help turn goals into collective action by allowing people to talk to each other about challenges in their own communities and ways they might approach solutions.

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Appendix A: Reference Exhibit Descriptions

Figure A1. "*Protege/Protect" exhibit where visitors design, test, and iterate cushions for bike helmet safety.*

Figure A2. *"Colabora/Collaborate" is a garden game where visitors design, test, and iterate with the aim of increasing yield by choosing plants that benefit one another.*

Figure A3. "*Vuela/Fly" is an exhibit where visitors design, build, test, and iterate kite models to generate electricity.*

Figure A4. *Community Workshop is a space where visitors create their own biomimicry inspired designs.*

Appendix B: Story Cycle 1 Data Details

Although the exhibit components had not yet been created, storytelling ambassadors had opportunities to engage with exhibit component prototypes. The aspiration for Cycle 1 was, “Caregivers (and educators) see that an engineering practice exercised at a DOT exhibit connects to their everyday lives.”

As mentioned previously, definitions for terms were reviewed, discussed, and agreed upon by the research team. During this cycle, the OMSI researchers presented an initial set of terms and definitions for the entire research team to discuss, revise and come to an agreement. A list of the Cycle 1 definitions and terms are in Appendix C.

Data Collection

With few exceptions, data collection followed the procedure previously discussed in the Data Collection Overview section. During this cycle, three storytelling ambassadors (one of the storytelling ambassadors had to take a leave of absence due to a family emergency and did not present her story during Cycle 1), four researchers (three to observe the storytelling sessions and one to coordinate the logistics and time keeping), and three active audience participants (one educator from Fleet Science Center, a project partner—and two caregivers, recruited by Fleet) met virtually using the Zoom communications platform.

Storytelling Ambassador Data Review

In this cycle, the storytelling ambassadors independently read through one data source at a time to identify words, phrases or sentences that help address the question of how story choices may have contributed to perceptions of relevance; in content analysis parlance, these phrases or sentences are called, “units of meaning.” Once units of meaning were identified, storytelling ambassadors were asked to categorize their units of meaning as to whether they provided evidence for relevance connections made by the active audience, choices or approaches that worked in supporting perceptions of relevance, or suggestions for ways to improve their story. After the units of meaning were categorized for a single data source, storytelling ambassadors were asked to share with the group the general takeaways they had distilled from the data for each of the three categories: relevance connections made, effective choices, and how to

improve. The storytelling ambassadors discussed the takeaways and a list of the group's findings was recorded. For items in the category of relevance connections made, storytelling ambassadors were asked to categorize the type of relevance perceived (association, usefulness, or identification). This process was repeated for each of the data sources. Additionally, to better understand the data, storytelling ambassadors created individual conjecture maps using the fillable Conjecture Map worksheet (Appendix D).

Cycle 1 Findings

Storytelling Ambassadors Data and Findings

Storytelling ambassadors noticed that opening with a *social field of focus* with a *personal impact range* helped build rapport with the audience, suggesting the use of enticing and intriguing statements and questions to hook the audience and move the story forward. The content of the story typically resided in the social and socio-scientific field of focus while increasing the impact range to include both personal and local elements. Key strategies in the content section of the story included coupling the scientific engineering practices with social contexts, using many examples of engineering practices in day-to-day life, being specific and explicit that the purpose of the conversation and story was engineering practices, naming the practices, and talking about the exhibit as an experience where they exercised the practices with their daughters or larger family. The invitation portion of the conversation utilized the same field of focus and impact range elements as the content section, namely social and socio-scientific fields of focus with both personal and local impact range. Storytelling ambassadors identified questions as essential to their invitations—specifically, personal questions about applying the practice.

Overall, storytelling ambassadors noticed they were very successful eliciting connections of association relevance between engineering practices and day-to-day life, and slightly less successful at helping the audience see the association relevance of the exhibit to their selected engineering practice, and see the usefulness relevance of their engineering practice to day-to-day life. Storytelling ambassadors felt they could improve at eliciting connections of usefulness relevance between engineering practices and day-to-day life, as well as improve at eliciting connections of association relevance between exhibits and day-to-day life.

OMSI Researcher Data and Findings

In order to better understand the data, OMSI researchers created a data visualization referred to as a *mosaic*. The mosaic attempted to represent the attributes, impact ranges, and fields of

focus used in the stories and conversations. This mosaic uses hue for each field of focus and shades for the impact ranges (Figure B1).

	Social	Socio-scientific	Scientific
Personal			
Local			
Global			

Mosaic Legend

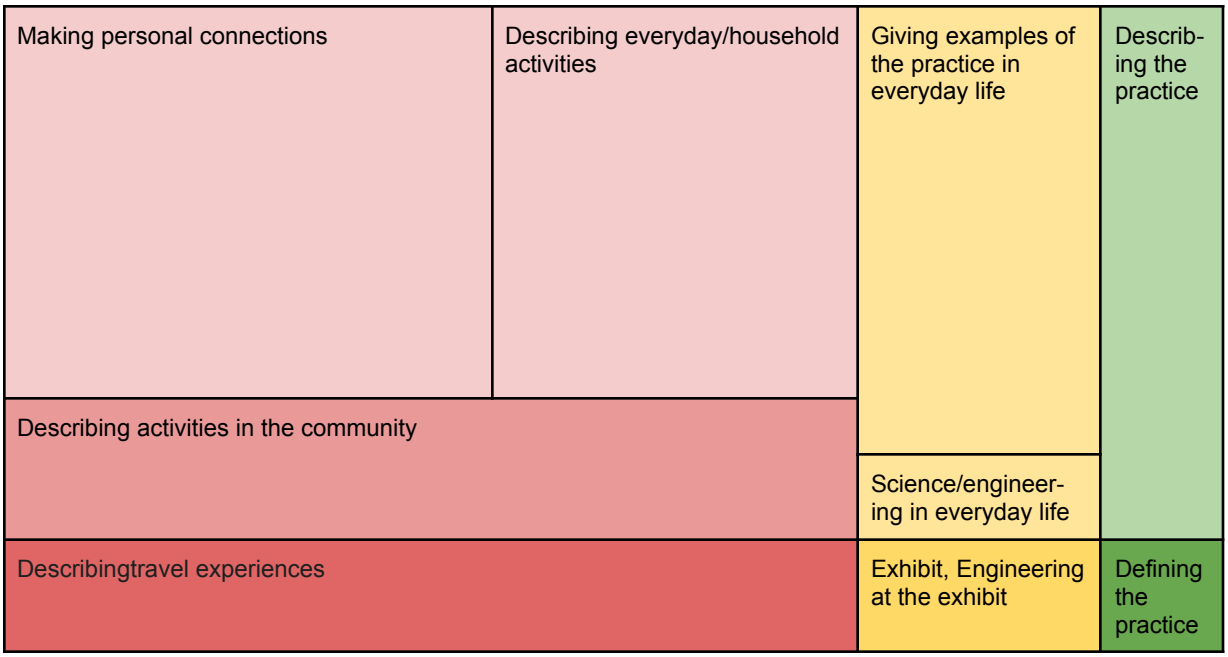

Figure B1. *Cycle 1 story and conversation mosaic, a data summary visualization*

The mosaic shows that the stories and conversations spent the most amount of time in the social field of focus. The impact range of the stories and conversations were primarily personal—even when the field of focus was socio-scientific. The content in the data suggested this personal and social time was used to connect and build rapport with the audience.

This mosaic was shared with the storytelling ambassadors for feedback and discussion. It was used to help identify similarities in the findings between OMSI researchers and storytelling ambassadors. Through these conversations, the mosaic was used to facilitate the creation of the questions and ambitions for Cycle 2.

Appendix C: Cycle 1 Definitions

These Cycle 1 definitions for key terms were provided by OMSI researchers and discussed with the storytelling ambassadors as part of the program. These definitions were iteratively updated each cycle. Cycle 1 definitions include:

- ***Everyday engineering*** is an approach to problem-solving in which people apply strategies and practices to identify and address challenges in their own lives and in their communities through an iterative series of steps.
- ***Field of focus*** (Kotkas et al., 2016) is a phrase that describes how concepts are included, or how scientific concepts are framed. The following fields of focus, definitions, and examples are excerpts from Kotkas.
    - ***Scientific***: A focus on scientific concepts, scientific problem solving, or descriptions of a science related career. Everyday life is incorporated minimally (a couple of examples of applications or everyday life is mentioned to induce familiarity in students). “Carbon-nature of life.” Contains word carbon as a chemical element. “Why do cans of Coca-Cola sink, while cans of Coca-Cola zero float.” Sinking and floating as physical terms, scientific problem. (p. 202)
    - ***Socio-scientific***: Covers scientific issues in social context. These scenarios cover topics that do not have one specific answer. Connect scientific concepts closely with everyday life. “Plastics-reduce the use.” Plastics as a chemical term; the overuse of plastics is a social problem. (p. 202)
    - ***Social***: Covers a social issue/problem, which has little to do with science. Economic aspects are a key focus. “Lara (16) is pregnant”. Teenage pregnancies as a social problem. (p. 202)
- ***Impact range*** (Kotkas et al., 2016) is a phrase that describes on what level students are affected or how the issue presented affects people (p. 202).
    - ***Impersonal***: Does not impact on listeners personally, locally or globally, but can be important for some specific community (for example, scientists, doctors, product users). “Stumbling over biodiversity-plant diversity on paving cracks”. Is important to botanists as a part of the scientific community. Contains scientific words like biodiversity. (p. 202)
    - ***Personal***: Affects learners themselves, or close relationships (family, friends). “Can you find a way to make your family happier with the electricity bill?” Addresses student by the words, you and your family. (p. 203)
    - ***Local***: Affects the local community to which listeners belong; does not need to affect listeners personally, but can have impact on a student (i.e. school community, local at village/city/country levels). “Toxic fish? Environmental toxins in fish from Baltic sea.” Toxins in fish of Baltic sea is a problem for the surrounding areas of Baltic sea. (p. 203)
    - ***Global***: Has a global impact, and can have direct impact on student, but the impact can also be indirect. Environmental problems belong here. “Stop having sex-the world is overpopulated” Overpopulation is a global problem, causing problems with food supplies, energy, and illnesses (p. 203).

Appendix D: Cycle 1 Conjecture Map

Study 2 Storyteller Conjecture Map v.8.17.22 Cycle:_____ Name:_____ Date:_____

Purpose: To tell a story that helps caregivers and educators to see the value and usefulness of the engineering practices fostered at DOT exhibit connected to their everyday life practices.

Opening: How does the opening connect to the active audience lives?

Field of focus: Scientific Socio-Scientific Social **Impact range:** Impersonal Personal Local Global

Content: How does the content allow the active audience to see the usefulness between the DOT exhibit engineering practices and engineering practices in their everyday lives?

Field of focus: Scientific Socio-Scientific Social **Impact range**: Impersonal Personal Local Global

Invitation: How does the invitation initiate a conversation about connections in the active audience lives?

Field of focus: Scientific Socio-Scientific Social **Impact range**: Impersonal Personal Local Global

Exhibit:_____ Engineering practice(s):_____

Genre:_____ Style:_____

Active audience response [can include impressions, reactions, questions]

Storytellers response, reaction, or question [Sparking connections]

Appendix E: Story Cycle 2 Data Details

Data Collection

In Cycle 2, the active audience consisted of an educator from the Fleet and three caregivers. The aspiration for this cycle was, “Caregivers (and educators) see the value of an engineering practice at a DOT exhibit BECAUSE that practice is useful in their day-to-day lives.” The research team revised some definitions of key terms that were used in Cycle 1. The modifications typically involved changing words to create greater clarity or modifying the examples provided with terms to better align with the project. Additionally, definitions for relevance-related terms were added to the list. This updated list can be found in Appendix F.

Cycle 2 Findings

Storytelling Ambassador Findings and Conjecture Visualization

After data review in Cycle 2, the storytelling ambassadors used their notes in the reflection matrix to create individual conjecture visualizations, and then proposed a single visualization as a group. The visualization included the strategies storytelling ambassadors determined were important as well as the purpose of those strategies and what the ambassadors hoped the audience would gain or how they would react (Figure E1).

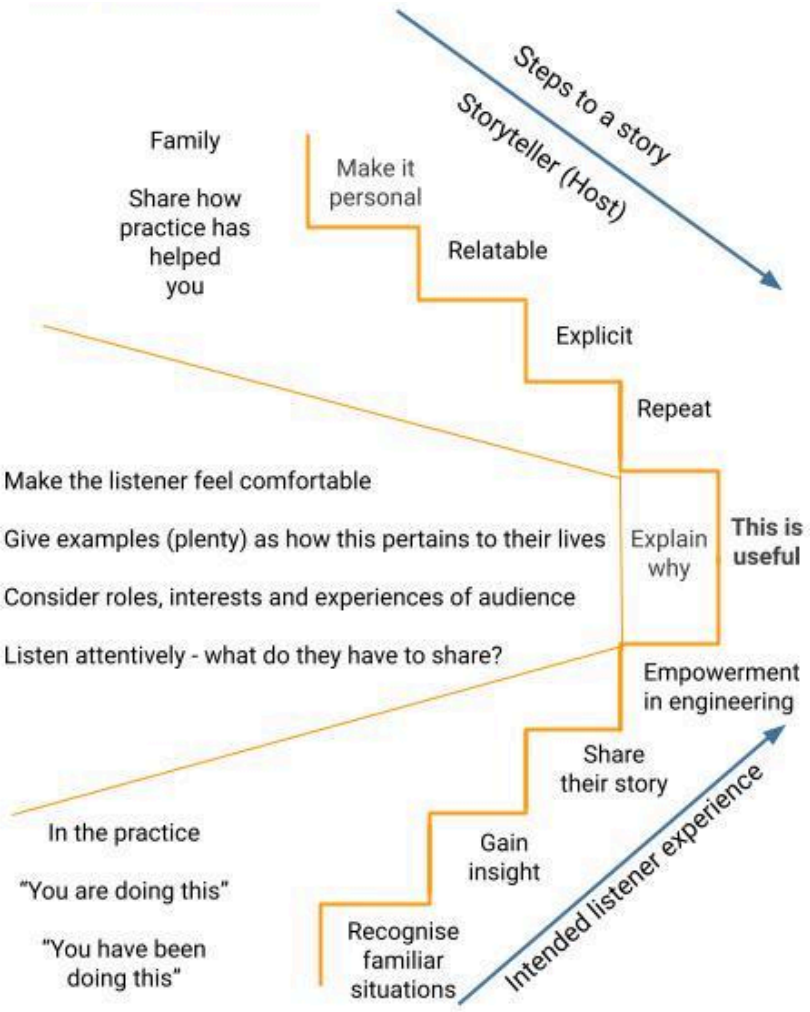

Figure E1. Story*telling ambassadors' Cycle 2 conjecture visualization*

The storytelling ambassadors maintained that social and personal elements were essential when initially building rapport to help the audience relate, but that their stories had more of a socio-scientific field of focus and a local (community) impact range compared to those in Cycle 1. Their ultimate goal was to help listeners see the value of an engineering practice at a DOT exhibit because that practice is useful in their day-to-day lives. Still, storytelling ambassadors recognized that it was also essential to help the audience feel comfortable and self-generate connections. Storytelling ambassadors identified four characteristics of an effective story in their visualization. To do this, a story should be personal (include elements of the storytelling ambassador's own life and experiences) and relatable (be familiar to the audience); include connections to engineering, the exhibit and the practices should be explicit, and important points should be repeated frequently.

OMSI Researcher Findings

During this cycle, Cycle 2, OMSI researchers focused on trying to better understand the active audience members' perceptions of the usefulness relevance of the engineering practices. To do this, they created a data summary visualization to illustrate the emergent relevance in data from the active audience. The visualization contains squares of different hues based on the type of relevance (e.g. yellow for association, blue for usefulness, purple for identity, and pink for connections to life) and shades of the hue for the different situations during which the relevance was illustrated in audience responses. The size of the squares differ relative to the prevalence of the occurrence (Figure E2).

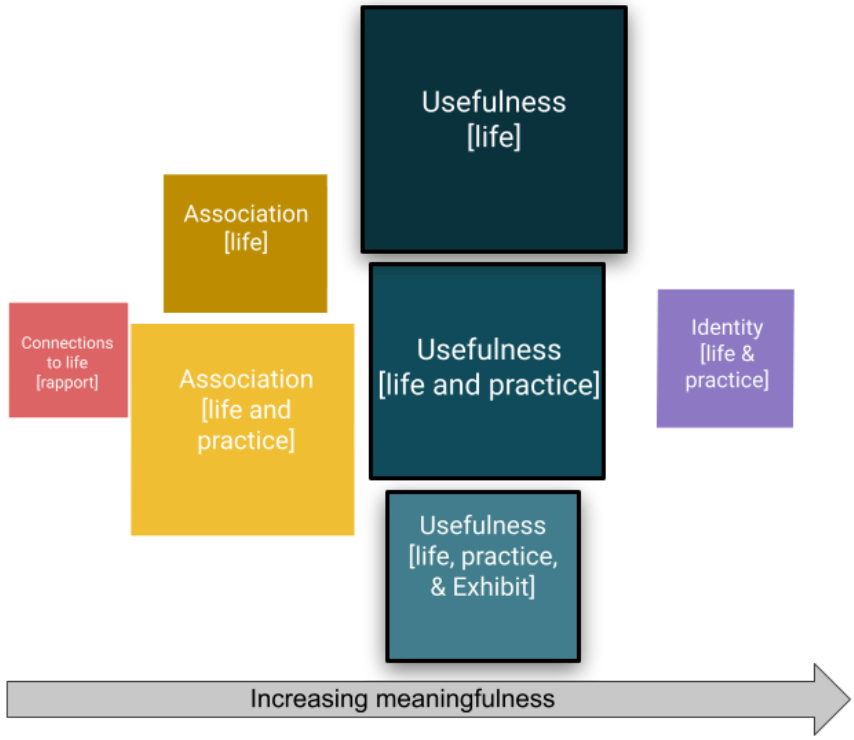

Figure E2. *OMSI researchers' Cycle 2 representation of emergent relevance from active audience data*

Usefulness was the most prominent form of relevance, with connections often to life and an engineering practice. Though less frequent, usefulness relevance also had connections with the exhibit in relation to life and practice. The Cycle 2 visualizations from the storytelling ambassadors and the OMSI researchers were shared and discussed with the whole research team. The visualizations and conversations helped the team to identify Cycle 3 research questions and aspirations.

Appendix F: Cycle 2 Definitions

These definitions were updated each cycle. The Cycle 2 definitions for key terms were substantially refined for greater relevance to the context of the research and incorporate learnings and perspectives gained from the previous cycle. Changes are indicated by underlined text.

- ***Everyday engineering*** is applying a series of strategies and practices to solve problems in our lives and communities.
- ***Field of focus*** (Kotkas et al., 2016) is a phrase that describes how STEM concepts are included or framed (p. 202).
    - ***Scientific***: A focus on STEM concepts, problem solving, or descriptions of a STEM related career. (p. 202). Includes planning and brainstorming as engineering practices.
    - ***Socio-scientific***: Covers STEM concepts in social context. These scenarios cover topics that do not have one specific answer and connect STEM concepts closely with everyday life (p. 202). My family and I brainstorm meals each week.
    - ***Social***: Covers a social issue/problem, which has little to do with STEM content. Social aspects are a key focus (p. 202). Lara doesn't get enough to eat. Food insecurity is something we should all be concerned about. Food insecurity is a social problem.
- ***Impact range*** (Kotkas et al., 2016) is a phrase that describes on what level audiences are affected or how the issue presented affects people (p. 202).
    - ***Impersonal***: Does not impact on listeners personally, locally or globally, but can be important for some specific community (for example, scientists, doctors, product users) (p. 202). Space launches are attended by more people now than ever.
    - ***Personal***: Affects audiences themselves, or close relationships (family, friends) (p. 203). Can you find a way to make your family happier with the electricity bill? Addresses audiences with words you and your family.
    - ***Local***: Affects the local community to which listeners belong; does not need to affect listeners personally, but can have impact on the audience (i.e. school community, local at village/city/country levels) (p. 203). "Does your local library have enough books?
    - ***Global***: Has global references, and can have direct impact on the listener, but the impact can also be indirect. Environmental problems belong here (p. 203). I bet growing up in Colombia was interesting. Refers to a non-local connection the person has. Climate change affects us all. References a global issue.
- ***Relevance*** is a connection that has personal meaning.
    - ***Association relevance*** is when a person connects an object, activity, or information to some other object or memory (Priniski et al., 2018, p. 12).
    - ***Usefulness relevance*** is the perception that an object, concept, or activity is of value or utility for achieving personal or community goals..
    - ***Identification relevance*** is when a person relates an object, activity, or information to an individual's identity (Priniski et al., 2018, p. 12).

Appendix G: Active Audience Post-Story Questionnaire

Cycle 1 and Cycle 2

1. What did you and the OMSI staff member talk about during your conversation?
2. Please share connections you made, if any, between parts of the conversation and your everyday life.
3. What, if anything, about the story helped you imagine how engaging with the exhibit might be useful in your everyday life?
4. What, if anything, about the story helped you make connections between what you could do at the exhibit and problem solving in your everyday life?
5. What do you think the OMSI staff can do differently to help you appreciate the story more?
6. Any other comments to add?

Cycle 3

1. What did you and the OMSI staff member talk about during your conversation?
2. Please share connections you made, if any, between the conversation you had and your everyday life.
3. What are you taking from this conversation?
4. What, if anything, about the story helped you see how the exhibit activity might be useful for problem solving in your life?
5. What do you think the OMSI staff can do differently to improve their story, and the telling of it?
6. Any other comments to add?

Appendix H: Storytelling Ambassador Story Day Questionnaire

Cycle 1 and Cycle 2

1. What about the story do you think helped the active audience participants see the value and utility of the exhibit component?
2. What examples of choices for your opening, content, and invitation do you believe supported connections to the active audience's lives?
3. What examples of choices for your opening, content, and invitation do you believe hindered the creation of a connection to the audience's lives?
4. Consider what you were trying to achieve versus what happened in the story sharing sessions. What would you do next time regarding your story content and the choices used and why?
5. [This question was added in Cycle 2; it was not used in Cycle 1]: Is there anything else you would like to share?

Cycle 3

1. What about the story do you think helped the active audience members see the value and utility of the engineering practice at exhibit component?
2. What examples of choices for your opening, content, and invitation do you believe supported connections [*useful relevance*] to the active audience's community and/or community challenges?
3. What examples of choices for your opening, content, and invitation do you believe hindered the creation of a connection [*useful relevance*] to the audience's community?
4. What questions or prompts in the conversation [dialogue] do you believe helped the audience to express usefulness relevance with respect to their community?
5. Consider what you were trying to achieve versus what happened in the story sharing sessions. What would you recommend to do differently regarding your story [content and the choices] and the questions during the dialogue? and why?
6. Is there anything else you would like to share?

Appendix I: Storytelling Ambassador Story Session Questionnaire

Cycle 1

1. How well do you think this sharing of your story went?

Not well at all				Very well
1	2	3	4	5

2. Please explain your rating about what went well and what did not go well.

3. How well do you think you connected the engineering practice at the exhibit to the audience's everyday lives?

Not well at all				Very well
1	2	3	4	5

4. What was the most impactful response you received?

Cycle 2

1. How well do you think this sharing of your story went?

Not well at all				Very well
1	2	3	4	5

2. Please explain your rating about what went well and what did not go well.

3. How well do you think you communicated the value of the engineering practice at the exhibit to the audience's everyday lives?

Not well at all				Very well
1	2	3	4	5

4. What about the dialog has remained with you? why?

5. Is there anything else you would like to share?

Cycle 3

1. How well do you think this sharing of your story went?

Not well at all				Very well
1	2	3	4	5

2. Please explain your rating about what went well and what did not go well.

3. How well do you think you connected the engineering practice at the exhibit to the audience's community and/or community challenges?

Not well at all				Very well
1	2	3	4	5

4. What was the most impactful response you received?

5. Is there anything else you would like to share?

Appendix J: Storytelling Ambassador Reflection Matrix

Cycle 2

Think about the choices you made when creating your stories. What options did you consider? What were you trying to achieve and why did you think that approach would be successful?		
What were some approaches and choices you explored with this story? For example: Starting by talking about the exhibit, making direct parallels between the exhibit activity and an everyday life activity, using a real-life example that was engaging, etc.	**How did you think this approach would benefit your story? What purpose would it serve?**	**Why did you think it might work?**
Take a look at the data from Cycle 2 Story Day. What evidence do you see that the active audience saw relevance or value in what you were talking about? What was it about your story or dialogue that helped them make a connection? What type of connections did the active audience make? Why do you think what you said helped make that connection?		
What is a relevance connection your conversation made with the active audience? What type of connections did the active audience make? What evidence shows this? What kind of relevance connection is this (Association? Usefulness? identify?)?	**What about your conversation, do you think helped make these connections?** What excerpts from the data can support this? What field of focus and impact range was your story in at the time?	**Why do you think what you said helped to make that connection?** What evidence from the active audience do you have?

Cycle 3

What evidence do you see that the active audience saw relevance in what you were talking about? What type of connections did the active audience make? What was it about your story or dialogue that helped them make a connection?	
What are some examples of relevance connections the active audience <u>expressed</u>? Identify a passage from the transcript that supports this. What type of relevance is it (Association, Usefulness or Identification)?	**Which of the relevance connections you identified demonstrate fulfillment of the cycle 3 aspiration?** Write the full text of a passage where the <u>AA expressed usefulness or value of the practice for addressing community level challenges.</u>
Identify a passage from the story transcript that contributed to an expression of usefulness relevance. Write down the session, the page number on the transcript, and the first and last several words of the example separated by ellipsis (...)	**What was the general approach and/or choice for each of the passages you identified?**

Appendix K: Cycle 3 Definitions

These definitions were iteratively updated each cycle. The Cycle 3 definitions for key terms were lightly refined to reflect the shifts in perspective gained from the previous cycle. Changes in the definitions for Cycle 3 are indicated by underlined text.

- ***Everyday engineering*** is applying a series of strategies and practices to approach problems in our personal lives and in our communities.
- ***Field of focus*** (Kotkas et al., 2016) is a phrase that describes how STEM concepts are included or framed (p. 202).
    - ***Scientific***: A focus on STEM concepts, problem solving, or descriptions of a STEM related career (p. 202). Includes planning and brainstorming as engineering practices.
    - ***Socio-scientific***: Covers STEM concepts in social context. These scenarios cover topics that do not have one specific answer and connect STEM concepts closely with day-to-day life (p. 202) for a group of people or community. Reveal the structural causes or social determinants of a problem. My family and I brainstorm meals each week.
    - ***Social***: Covers a social issue/problem, which has little to do with STEM content. Social aspects are a key focus; focuses on group efforts, not individual efforts (p. 202). Lara doesn't get enough to eat. Food insecurity is something we should all be concerned about. Food insecurity is a social problem.
- ***Impact range*** (Kotkas et al., 2016) is a phrase that describes on what level audiences are affected or how the issue presented affects people (p. 202).
    - ***Impersonal***: Does not impact on listeners personally, locally or globally, but can be important for some specific community (for example, scientists, doctors, product users) (p. 202). Space launches are attended by more people now than ever.
    - ***Personal***: Affects audiences themselves, or close relationships (family, friends, neighbors) (p. 203). Can you find a way to make your family happier with the electricity bill? Addresses audiences with the words, you and your family.
    - ***Local***: Affects the community to which listeners belong; does not need to affect listeners personally, but can have impact on the audience (i.e. school community, local at village/city/country levels) (p. 203). Considers trends or patterns that shape conditions for a community or group of people. "Does your local library have enough books?
    - ***Global***: Has a global reference, and can have direct impact on the listener, but the impact can also be indirect. Environmental problems belong here (p. 203). I bet growing up in Colombia was interesting. Refers to a non-local connection the person has. Climate change affects us all. References a global issue.
- ***Relevance*** is a connection that has personal meaning
    - ***Association relevance*** is when a person connects an object, activity, or information to some other object or memory (Priniski et al., 2018, p. 12).
    - ***Usefulness relevance*** is the perception that an object, concept, or activity is of value or utility for achieving personal or community goals.
    - ***Identification relevance*** is when a person relates an object, activity, or information to an individual's identity (Priniski et al., 2018, p. 12).

Appendix L: Constructing the Model

Constructing the base model

The EP&UDL Study was grounded in theoretical concepts which can be developed into a model using a basic structure from the Ecological Model of the Communication Process (Foulger, 2004). The following paragraphs describe the initial construction of the EP&UDL Model using just theoretical concepts (before final data was taken into account) (Figure L1). The final EP&UDL Model is in the main body of the paper in Figure 5.

This model contains three boxes, each of which represents a key component in communication, as identified by Foulger (2004). The center box represents the public communication topic, *"Engineering practices exercised in exhibit are useful for accomplishing day-to-day goals, including community-related goals."* The bottom of this box explicitly states that the communication channel in this campaign is interpersonal and that the focal engineering practices in the campaign come from the C-PIECE Framework (Randol et al., 2023).

The box on the left represents the conversation host/storytelling ambassador and will contain the choices the conversation hosts make to elicit connections to engineering practices and the usefulness in day-to-day life. The box contains elements the conversation hosts' expected to incorporate in their stories: engineering practices, fields of focus, impact ranges, conversation components, communication strategies, and question types. The bottom of the box lists some of the key approaches used to design the study, the Storyteller Program, and the Story Days.

The box on the right represents the active audience participant and will contain the connections active audience participants make during the conversation. The bottom of the box on the right refers to the theoretical interest in the active audience participants' perceived usefulness relevance of engineering practices in day-to-day life, including community experiences.

The arrow below the boxes points out that the conversation host and the active audience participant share perspectives of and relationships with caregiver and/or educator. The arrow above the boxes points out that the conversation is co-created by the conversation host and the active audience participant.

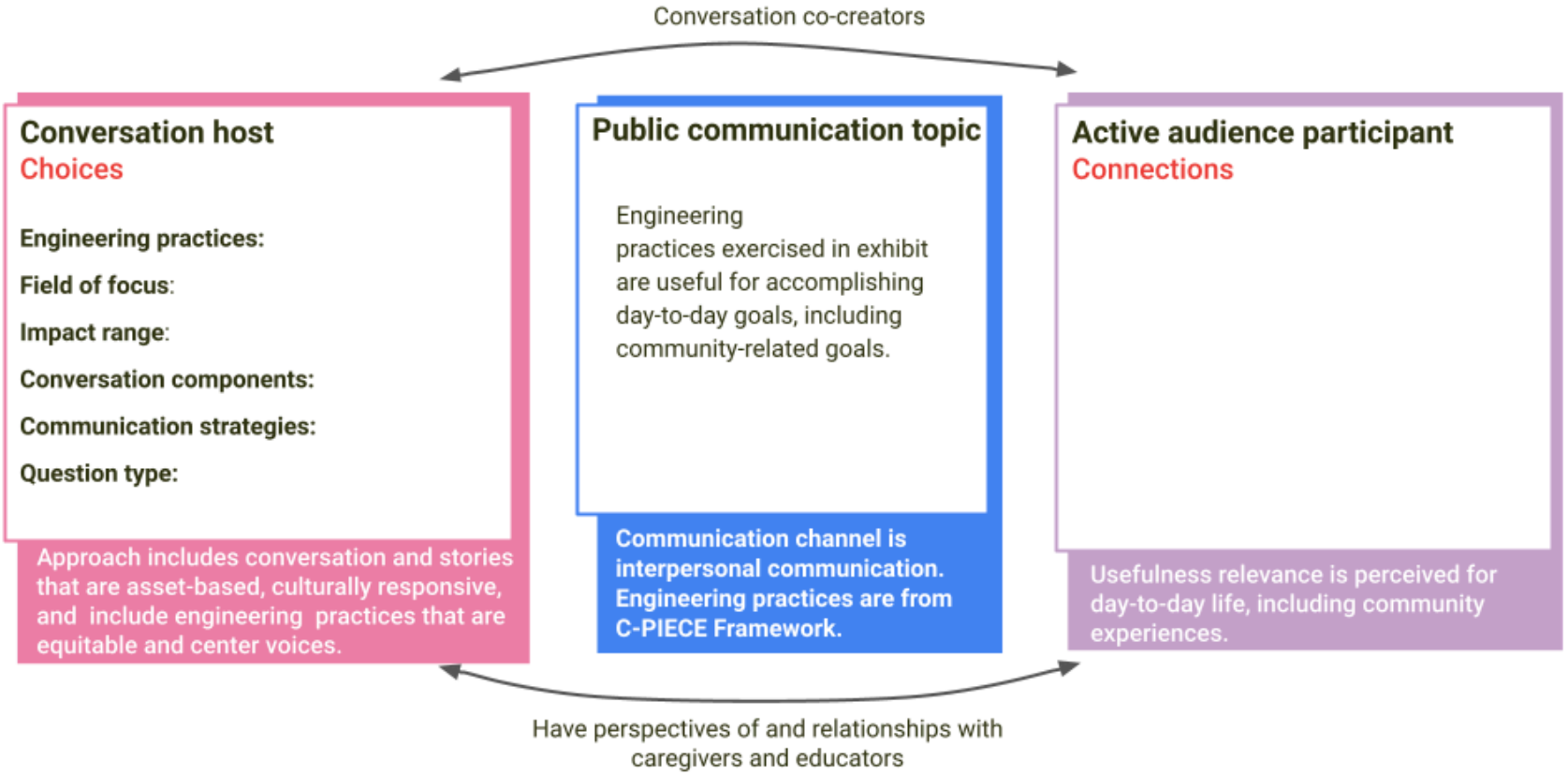

Figure L1. *This is a sketch of the theoretical elements in the model of conversation participants' choices and connections on the topic of Engineering Practices and Usefulness in Day-to-day Life* (*EP&UDL Model).*