



NEGOTIATING LEADERSHIP AUTHORITY

A Shift in Authority: Applying Transformational and Distributed Leadership Models to Create Inclusive Informal STEM Learning Environments

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Abstract Research across fields has converged on the importance of grounding STEM learning in learners' personal, social, and cultural experiences. This article describes how distributed and transformational leadership models in science centers can enable a paradigm shift away from unidirectional communication of scientific information from institution to visitor, and toward practices that prioritize the diversity of visitors' own experiences and their agency as learners and thinkers. Three case studies (on exhibit design, facilitation, and activity development) illustrate how adopting elements of distributed and transformational leadership models allowed project teams at the New York Hall of Science to operationalize the theoretical foundations of our museum's educational philosophy across multiple areas of the organization. Across the three projects, supporting visitors' agency and centering their diverse perspectives and prior knowledge required a parallel shift toward increased collaboration and agency among staff with diverse roles and areas of expertise.

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INTRODUCTION

Science centers are adapting to rapid shifts in the public's relationship to scientific information. The methods and processes of science are continually changing, and technological advances combined with an increasing appetite for social interaction and dialogue have made unidirectional delivery of static knowledge unrealistic and unsustainable for institutions, and unappealing to our audiences. At the same time, public interest in civic and social engagement with scientific issues has grown and diversified, revealing a desire for action that motivates public engagement and learning for many different audiences (Falk, 2016; Stilgoe et al., 2014).

These societal trends mirror findings from decades of research across fields about how people learn and what makes museum experiences powerful (Falk & Dierking, 2016; National Academies of Sciences, Engineering, and Medicine, 2018). From this work, we know that learning is deeper and richer when learners have opportunities to actively discover, elaborate, and expand on scientific ideas, rather than passively receive information. We also know that learning is a social and situated phenomenon. The interactions that occur among peers, within family groups, among strangers, and with educators in museums are a platform for engaging with scientific ideas and making sense of these experiences over time (Falk & Dierking, 2016; Rogoff et al., 2016).

This research paints a picture of learning that extends far beyond the communication and reception of scientific facts. The field of science education has articulated the need for learning environments to involve learners not only in constructing knowledge, but also in deciding what is worth knowing and how learning should take place (Stroupe, 2014). Prioritizing visitors' agency — their power to shape what and how they learn — has become increasingly central in educational efforts that aim to involve learners in using scientific practices to understand and change their worlds (Miller et al., 2018). While museums have long integrated “hands-on” and “interactive” experiences through various types of interface design and mixed media, this more recent research calls on science centers to look beyond these well-established design elements to consider how exhibits can make connections to the prior knowledge and cultural practices that shape how visitors approach and interpret their museum experiences. By embracing the complexity and individuality of visitors' experiences as the foundation of learning, science centers can potentially offer more equitable and inclusive STEM experiences that welcome diverse perspectives and validate all learners' pathways toward STEM learning.

Carrying out a fundamental shift in the nature of the experience we offer to visitors requires making substantive, long-term changes in how we approach the planning and the implementation of those experiences. This shift necessitates widespread change in organizational culture and leadership models to align resources and sustain engagement across every dimension of our organizations in service of this complex goal. It also requires leveraging science centers' capacity to create public spaces for creative, social, and equitable engagement with STEM. Informal learning institutions have fewer structural constraints than formal institutions, and this freedom creates opportunities to engage more directly with audiences around scientific concepts and practices (McCallie et al., 2009). Even so,

moving away from science communication and toward deeper visitor engagement requires relinquishing some control and striking a balance between our roles as trusted sources of established knowledge and as advocates who frame STEM learning as an open, contingent, and on-going enterprise.

Within our own institution, we have pursued distributed and transformational leadership models in order to create learning environments that prioritize visitors' agency. Transformational leadership models involve engaging staff in working towards an inspirational vision for the future (Avolio & Yammarino, 2013; Bass, 1985), and distributed leadership emphasizes the collective processes through which teams work together to create change (Avolio et al., 2009; Carson et al., 2007). Applying these models across multiple projects has allowed us to evolve and align our internal practices to collaboratively work toward long-term goals for our institution. Distributed and transformational leadership models have four qualities that have been particularly relevant in our work:

1. Both leadership models involve *articulating aspirational goals* that staff across teams can identify with and use to guide their work (Judge & Piccolo, 2004). In distributed leadership models, this involves teams working together to establish a shared vision (Avolio et al., 2009). At the New York Hall of Science (NYSCI), senior leadership began redefining NYSCI's educational philosophy in 2010, with a goal of shifting the design of exhibit and visitor experiences from more traditional forms of science communication toward a focus on visitor agency, inclusion, and ownership over STEM learning, using the phrase *Design, Make, Play* to encapsulate this vision. This new approach used compelling and playful experiences as an anchor for exploration, skill-building, and problem-solving, drawing on research in developmental and cognitive psychology and the learning sciences (Honey & Kanter, 2013).
2. In these models, project teams *honor individuals' diverse expertise* and engage staff across roles and at multiple levels. Organizational learning is fostered when individuals from across the organization come together to actively contribute knowledge, skills, and ideas toward a common goal (Avolio et al., 2009; Bass, 1985; Carson et al., 2007). At NYSCI, enacting our ambitious educational philosophy required exhibit developers, informal educators, and learning scientists to work together to rethink our processes for creating learning experiences, and to generate new strategies that positioned museum experiences at the critical intersections among scientific concepts and practices, research on learning and development, and an understanding of visitors' priorities and points of view.
3. *Support for risk-taking and experimentation* encourages teams to embrace uncertainty and approach their work in new ways. Creating a culture of learning, in which staff see themselves as agents of change, empowers teams to redefine their practices in an ongoing and iterative way that fuels continual improvement (Hein, 2012; Kristinsdóttir, 2017; Roberts, 1997). In our own institution, implementing new pedagogical strategies required us to explore new approaches to exhibition development. We questioned deeply held assumptions about how

STEM learning can play out in museum spaces, and how designers and educators can welcome visitors' perspectives and interests. Between 2011 and 2015, we created two large, innovative exhibitions — *Design Lab* and *Connected Worlds* — which replaced some of the museum's older, more didactic exhibits. These exhibitions gave our visitors new opportunities to pursue their own goals and ideas in environments that focused on making, problem-solving, and creativity. These additions to the museum floor necessitated further experimentation across departments to address the challenges that arise when visitors have so much autonomy. Complex materials and resources were needed to support day to day visitation, and at times, the newer experiences conflicted with visitors' own expectations about what science center experiences were “supposed” to be like, or with older exhibit areas that remained in other parts of the building. What we realized over time was that the challenges we observed in how visitors were engaging with the new exhibitions were not flaws in the instructional design of these experiences — rather, these disruptions were occurring because we, as an institution, needed to fully reorganize ourselves around the task of supporting STEM learning in new ways.

4. Transformational leadership models involve leaders and teams *guiding reflection* to synthesize knowledge and build collective understandings that can evolve over time (Bass, 1985; Senge, 2006; Vera & Crossan, 2004). This kind of reflection supports institutions in critically examining and disrupting current practices, and in making sense of observations as teams experiment with new approaches (Kristinsdóttir, 2017; Tran et al., 2019). This allows continual updating of the knowledge and internal frameworks that can guide further change. At NYSCI, teams engaged in ongoing reflection as they developed new tactics and opened up pathways for coordinated planning across operational and programmatic teams. This work helped us recognize that, despite the significant impact the new exhibitions had on visitors' experiences, we also needed to attend holistically to our long-term plan for the entire museum floor. An interpretive planning process in 2018 allowed us to delve more deeply into the question of how experiences across the entire institution could embody the museum's vision for supporting our visitors as learners with the agency to use STEM practices to pursue their own ideas and questions. Working across departments, we explored what it would mean to reinterpret the museum's more traditional, content-based exhibitions through this lens, and how to build an organizational culture and ways of working that would support this vision. Throughout this work, we thought holistically about the entire arc of the visitor experience and about how we might shift our practices in cohesive ways across the entire institution to provide more inclusive and equitable invitations into STEM learning as a way of thinking.

These four qualities of distributed and transformational leadership models (aspirational vision, diverse expertise, experimentation and risk-taking, and reflection) carried across multiple projects, and were enacted in distinct ways within various project teams. Throughout this work, we developed new, shared practices that were based on the expertise and leadership not of a single individual, but of individuals across the organization with diverse points of view, building on the collaborative aspects of learning that were at the heart of our guiding philosophy. In this way, shifting practices in our

museum to prioritize visitors' agency involved a parallel shift toward increased collaboration and agency in the hands of staff across many different parts of the institution.

In this article, we use three case studies to illustrate how our museum has brought together exhibits, public programs, visitor experience, facilitation, research and development to achieve these goals. The cases illustrate the practical and conceptual implications of a shift toward visitor agency on exhibit design, activity development, and facilitation strategies. By illustrating how these leadership practices unfolded in our own institution, these cases have broader implications for the field. The cases presented here show how embracing uncertainty and fostering a culture of experimentation and learning can begin to change institution-wide culture in a systematic and cohesive way (Hein, 2012; Hooper-Greenhill, 2007; Kristinsdóttir, 2017; Roberts, 1997; Schein, 1990). These coordinated efforts across different departments and with other institutions have allowed us to critically examine how our environments and programs were actually engaging visitors, and how our practices could be reimagined to prioritize inclusion and visitor agency.

CASE 1: REDEFINING AGENCY, QUESTIONING PERSPECTIVES, AND TAKING RISKS IN EXHIBIT DESIGN

In May, 2019, NYSCI hosted a workshop we called “Rethinking Authority and Visitor Agency (without breaking your museum).” This two-day event, sponsored by the National Science Foundation, brought together about thirty science center professionals to consider how our approaches to exhibit development and design might need to change in order to better serve not only science enthusiasts but all learners, including those who might not currently feel welcomed or included in a place like a science center.

This workshop called upon museum staff with very different roles to look critically at our *aspirational goals* of creating science centers that provide equitable learning opportunities to all visitors. The conference was planned and facilitated by members of NYSCI's research, exhibits and youth development teams, and also involved close collaboration among senior leaders, project managers, and research assistants. Attendees included exhibit developers and designers, informal learning researchers, educators, and museum leaders from across the country. Because the conference was concerned with both conceptual and concrete issues of design and visitor experience, we worked together to design a workshop that moved repeatedly between very practical, visitor-centered activities and reflective activities that raised broad, challenging questions about our work and our values.

We took risks in our approaches to designing and facilitating the workshop. We invited workshop participants, who came from many of our peer institutions, to observe visitors interacting with some of our oldest and most challenging exhibitions. We reflected publicly on our own shortcomings relative to our institutional mission and goals. We also acknowledged the importance of inviting colleagues in our home institutions to take risks with us, particularly as we tried to identify opportunities for improvement. And throughout, we embraced both active exploration and reflection, investing in

careful facilitation and protecting significant chunks of time to listen to one another, ask clarifying questions, and share and challenge one another's claims and conclusions.

In the first major activity of the workshop, we used design and prototyping processes that many participants were familiar with as the basis for *experimentation* with new approaches to exhibit design. Groups were asked to observe visitors interacting with specific exhibits, and to propose a redesign of that exhibit that would increase visitor agency in relation to the exhibit learning goals. Given the expertise and creativity of the group, these redesigns were insightful and responsive to the observations the groups had made about the strengths and weaknesses of each exhibit experience. However, in the course of reporting out on the redesigns and giving feedback on them, the group encountered a challenge that led us toward broader, more difficult questions to address. The group began to recognize that increasing the nominal interactivity of an exhibit — for example, by adding a talk back board or prompts to look for or ask questions about specific aspects of the exhibit content — might invite more activity, but this was not necessarily the same as cultivating visitors' agency. Thinking about how exhibits could be redesigned meant that participants often fell back on familiar design languages, but this process caused the group to question what "agency" really meant and looked like, and to critique whether the opportunities we provided for visitors to ask questions and share ideas were authentic invitations for diverse perspectives, or transparent attempts to guide visitors toward predefined learning goals.

Our resulting discussion was best encapsulated by one participant's simple comment, that "agency is not for us to give." By articulating this, we had opened up a question that was larger than an issue of the design of interactive elements in exhibitry. We began to engage in a more fundamental conversation about what the relationship between visitors and the learning goals of exhibits might need to be in a museum that seeks to privilege the agency and questions of all visitors. Our reflections on the familiar process of exhibit design pushed us toward more challenging discussions and led us out of our comfort zones as designers and educators.

This exercise highlighted important distinctions between creating inclusive exhibits that represent diverse perspectives, and creating exhibits that actually invite visitors' own ideas, knowledge, and questions. For example, one group considered how they might redesign the "Timeline of Mathematics History" in the well-known Ray and Charles Eames' exhibition, *Mathematica*. This timeline is significantly dated, both in its content and in its manner of representing major mathematical discoveries as the isolated work of single geniuses. The group proposed reworking the timeline to represent a much broader range of mathematical practices and ways of thinking, and to highlight the work of a much more diverse range of mathematicians. This approach directly addressed issues of representation and equity, but it also raised questions within the group: was there something inherent in the timeline that was fundamentally mismatched with the notion of visitors expressing their own agency as learners? As one attendee noted, "If you had really done a root cause analysis of what was wrong with this exhibit, from this perspective, you might break the whole exhibit."

Throughout this process, we considered the *diversity of our perspectives* as a group, and whether our practices honored visitors' points of view as well. The participants in the workshop drew on different bodies of knowledge about what exhibits were intended to do and how visitors interact with

them, based on their expertise as designers, educators, or researchers. The fact that each individual had slightly different expectations and understandings of how visitors engage with exhibits prompted deeper discussions about our practices. A critical point of tension was between wanting to invite all visitors to actively explore, to ask questions, and to feel welcome, but also wanting to retain and remain committed to our own perspective as scientists, science enthusiasts, and educators who hoped to convey certain ideas about what science is. As we discussed this tension, we realized that there was an unexamined group identity at the center of this discussion — a “we” who had an agenda and a set of beliefs. As one participant summarized it, “What do we value? Our visitors’ perspectives, or our own perspective?” We realized that we needed to challenge this unified, professionalized “we” and consider how that shared identity might be holding us back from imagining other ways to invite and center our visitors.

Before the second day of the workshop began, the facilitators and program planners met to consider how we might want to re-work the day. The first day had been productive, but had led us into some potential dead ends, at points in the discussion where the group seemed unsure about how to follow through on the implications of some of their insights. We responded to this challenge by modelling the kind of personal risk-taking that we hoped would shift our professional thinking. On the fly, we modified the day’s agenda. The day now began with the workshop facilitators each speaking about their own personal identities, and how those identities shaped their own relationships to this professionalized “we” that the group had referenced so frequently the day before. In fact, each of the facilitators — like all of us — sometimes felt outside of or different from this shared identity as experts, educators, and science authorities that was implied by our repeated reference to “our” perspectives, goals, and values as museum professionals.

The facilitators’ frank stories had a catalytic effect on our *reflection* as a group. Confronted with their peers’ descriptions of their own experiences of being different, of feeling outside of this professional community at times, many participants began to shift their thinking, drawing more of themselves — a fuller range of their own experiences and perspectives — into the conversation. This, in turn, allowed us to better imagine how our visitors might also only be bringing parts of themselves into our science centers, and to begin to think more deeply about how to design exhibits that invite them to bring their whole selves into the encounter. For example, one group was considering how they might re-conceive *Seeing the Light*, a set of phenomenon-based exhibits developed by the Exploratorium over twenty years ago that invite visitors to observe light- and sound-based phenomena. After observing visitors move through the space quickly, their initial ideas focused on prompting visitors to slow down and reflect. After reflecting more deeply on their own experiences, however, the team began to take a more learner-centered approach, exploring how the exhibit could be re-imagined more broadly to invite visitors to consider how they depend on light to understand the world, and to do this in ways that would be inclusive of people who are blind or who have low vision. Critically, this required thinking about a wider range of ways that visitors might experience visual phenomena in their daily lives, in order to ensure that there were multiple starting points and connections that tapped into visitors’ existing understandings and provided jumping-off points for further exploration.

This shift was reflective of the evolution of the whole group’s discussion, which allowed us to identify more strongly with visitors who may not know how to, may not want to, or may not be able to step into the roles we are offering to them in our museums. It also helped us recognize how much richer our exhibits could be for all learners if they were framed in ways that did not assume a uniform or generic audience of learners. A final critical stage in our discussion was to recognize that to some extent we all find ourselves in this “outside” position when we do not yet know something that someone else hopes we will learn. This was one way, we realized, to understand why designing for agency is so critically important to our shared goal of creating inclusive learning experiences. We concluded that our approaches to exhibit design are strengthened by drawing two critical lessons from the learning sciences and cognitive psychology. First, visitors will benefit if we provide them with opportunities to engage with new ideas on their own terms — by posing their own questions, taking action based on what they already know or believe, or otherwise sharing something that reflects their voice and experience. Second, our designs need to then invite visitors to explore the relationship between their perspectives and some new perspective, in a way that can lead to new insights.

Moving through these discussions reinforced our understanding that designing for agency requires the expertise of many different members of a museum staff — designers, developers, educators and learning scientists among them. It also deepened our understanding of the need for these team members to bring their full selves, and their experiences as learners, to bear on the collaborative process of designing experiences that invite our visitors to express their agency. Our willingness to take these risks together, as professionals and learners ourselves, is necessary to create true transformation in our museums, and to make our institutions safe environments in which our visitors can also be risk-takers.

CASE 2: RETHINKING FACILITATION TO PROMOTE AGENCY AND INCLUSION

A second project involved refocusing the facilitation strategies used by floor staff, in order to elevate visitors’ interests, questions, and experiences. Working toward this *aspirational goal* meant that facilitation needed to shift from didactic and content-based to open-ended and learner-centered, necessitating new training and professional development opportunities for floor staff.

NYSCI has a unique and longstanding youth development program that has been the cornerstone of our museum for the past 30 years. It prepares youth to act as ambassadors for our programs and exhibits, through a variety of activities including direct engagement with visitors on the museum floor. High school and college students, known as Explainers, are recruited from our local neighborhoods to facilitate public programs and engage with our visitors around the content and substance of our exhibits. For years, Explainers have participated in ongoing professional development, learning opportunities, and mentorship with museum professionals to help them develop communication skills and STEM knowledge, with the end goal of supporting visitors in grasping the science content behind NYSCI’s interactive exhibits and programs.

As our institution began to integrate more visitor-centered design and making experiences onto the museum floor, we also needed to shift Explainer training away from focusing on communicating scientific information and ideas, and toward following visitors' leads, encouraging their curiosity and questions, and supporting them in pursuing their own distinctive approaches to problems. Well-established facilitation techniques that had previously been used by Explainers to help visitors arrive at formal explanations for scientific phenomena would no longer be enough. Now, Explainers needed to be prepared to take on new roles as guides, discerning visitors' interests and nurturing visitor agency in tackling STEM-based challenges and questions.

At the same time, the need to transform facilitation practices was not entirely obvious to many of our experienced Explainers or even to our training team at the start. NYSCI's well-established training program was widely recognized in the museum field, and training staff had spent a significant amount of time and resources preparing Explainers to develop the content knowledge and facilitation strategies to engage visitors with the science content behind our exhibits. In turn, experienced Explainers derived a great deal of confidence and pride from developing this expertise, and many did not feel the need to change practices that seemed, from their perspectives, to be working successfully. To address these challenges, the staff leading the Explainer training program had to identify new indicators of success that Explainers could use to guide their interactions with visitors and that would call attention to different dimensions of STEM learning. Two parallel programs were instrumental in making this possible — a privately funded effort designed to empower our youth to be part of our institution's transformation, and a research program funded by the National Science Foundation that focused on supporting floor staff in reframing engineering practices in more equitable ways in their work with visitors. In both projects, project leaders worked with Explainers to transform their interactions with visitors by creating a culture of experimentation, ownership, and reflection, in which Explainers' perspectives and ideas were integral to the development of new facilitation approaches and museum experiences.

A first step in shifting Explainers' interactions with visitors was developing a shared language to describe what positive visitor engagement might look like. Rather than continuing down the typical path in which staff responsible for training floor staff would tackle this challenge on their own, we pulled together a cross-departmental team that *represented diverse perspectives*. The team members included the Explainers and Explainer trainers, education researchers, program developers, and exhibit designers. Each participant offered unique perspectives and areas of expertise: Exhibit designers had a deep understanding of the intention behind museum exhibits and activities, and program operations staff shed light on the disconnects between the intent of our designs and pragmatic operational concerns. Youth program staff articulated the core needs and practices that came into play in youth development. Explainers offered their first-hand experiences engaging visitors, and researchers provided expertise in the area of progressive child-centered approaches to STEM teaching and learning as a lens for reflecting on visitor interactions and Explainers' roles in that process. These multiple perspectives were critical to enriching the work of our youth development team and, more importantly, to laying a foundation for more widespread institutional change. This interdepartmental approach to leadership ensured that work was not "owned" by one department. Instead, the work relied on diverse

voices to better define and recognize the practices we were trying to disrupt and the support youth needed to deliver on the museum's mission for visitor-centered engagement.

Identifying what Explainers would need to know and be able to do required making room for *guided reflection* among members of the interdepartmental team. This guided reflection took many forms. For example, using prior research on engineering habits of mind as a guiding framework (National Research Council, 2009), we dedicated time to discussing how Explainers could support the design-based and maker-based learning experiences that were central to our new exhibits and our larger mission of fostering agency and inclusion. However, early on we learned that despite initial attempts in orientation and training sessions to introduce Explainers to learner-centered pedagogical approaches, Explainers still saw their key responsibility in visitor engagement to be that of content expert. To address this issue, the team worked together to create opportunities for Explainers to reflect on their own interactions with visitors and to think critically about their roles across different exhibits. As Explainers shared their experiences to help each other improve their work, their ideas about what constituted a meaningful learning experience and what roles they played in visitor engagement started to shift. By integrating Explainers' perspectives and experiences, the team was able to develop a shared language about the factors that influenced visitors' learning, as well as the challenges that sometimes arose in implementing new facilitation strategies. Enabling Explainers to actively contribute to redefining our approaches to visitor engagement was critical for allowing leadership to anticipate Explainers' needs and provide them with greater opportunities to see themselves as having agency in creating unique and personalized learning experiences for visitors.

In a recent NSF-funded project called *Formation of Engineers*, for example, three cohorts of Explainers have been involved in re-imagining how the museum presents engineering topics to our audiences and how Explainers engage visitors with the principles and purpose of engineering as a discipline. This project charged small groups of Explainers with designing public events, engineering activities, and STEM exhibits in collaboration with interdepartmental staff and external engineers. To encourage these youth to incorporate their personal perspectives into these collaborative tasks, the program provided multiple channels for the Explainers to reflect on their experiences. The interdepartmental team held bi-weekly meetings with the Explainers to support guided reflection on their ideas, plans, and designs for activities or events. In these meetings, the Explainers discussed their progress with training staff and project researchers, who provided help and direction to support Explainers make connections to their prior experiences and generate new questions to deepen and broaden their work with visitors. In particular, we returned to a set of engineering habits of mind as a core framework to guide the groups in iteratively developing their designs (National Research Council, 2009). Reflection questions focused on how their projects could use active participation to help visitors better understand how engineers think and act to solve problems — for example, “How might this activity invite a young visitor to use systems thinking?” or “How might this event encourage visitors to consider ethical issues while solving an engineering problem?” This reflection process created a safe space for Explainers to synthesize what they learned with other professionals and from their fellow Explainers. These collaborative learning opportunities allowed Explainers to experience that

their perspectives were valued, which resulted in their own increased sense of agency and authority to decide what to look at and experiment with on the museum floor.

These discussions served as a springboard for Explainers to *experiment* and transform facilitation practices for engaging museum visitors in museum exhibits. The shift in Explainers' practices from content delivery to listening to visitors and following their lead was new to everyone, and it was important to build a culture of experimentation in order to help Explainers feel supported and empowered to try new approaches, and sometimes fail. In particular, our youth leadership team responsible for training needed to create time and space to model an experimental mindset in their daily interactions with Explainers, actively challenging them to think about how they could inspire visitors to try things, as opposed to "teaching" or explaining. Explainers were also given ownership over choosing which activities would go out on the floor each day within our activity-based exhibits, and they have contributed to ongoing activity development and research efforts.

As Explainers have become more actively involved in contributing to new experiences on the museum floor, they have a great deal of ownership of what these experiences are and how they are facilitated. This kind of work enabled Explainers to see their individuality as an asset for refining their own facilitation styles to foster visitor-centered engagement. This was especially evident in the development of new science demonstrations. Traditional demonstrations required Explainers to demonstrate a scientific principle by displaying how something works, following a scripted line of questioning and performative tasks that highlight the science take-aways (e.g., demonstrating the properties of matter). A new demonstration (called *Design Time*) created collaboratively by the leadership and a team of Explainers involved modeling the engineering design process by introducing novel, whimsical materials and inviting visitors to collaboratively design a solution for delivering a ball from one side of the demo space to the other. Ultimately, this experiment inspired a larger reworking of our other more traditional, longstanding demonstrations (like cow-eye dissections) to allow for visitors to have more of a voice and an active role in choosing the direction and outcome of the demonstration process.

Overall, this work led to positive outcomes that have persisted in the institution. The distributed authority and shared responsibility across different departments brought to light the unique contributions of each individual and the critical need for cross-departmental collaboration in defining visitor engagement. This process ensured that the voices of the most important members in the team, the Explainers, were heard and valued, and that Explainers themselves had an active role in co-designing facilitated experiences and training materials.

CASE 3: TOWARD AN ITERATIVE AND EMPATHIC APPROACH TO ACTIVITY DEVELOPMENT

A third project grappled with the practical realities of implementing an aspirational educational philosophy in the context of design-based activities, and the challenges of creating appealing learning experiences that connect to visitors' prior experiences and expectations.

NYSCI's *Design Lab* exhibit space was envisioned as an imaginative space for open-ended design and engineering. At 10,000 square feet, it has five thematically distinct areas for different types of engineering design activities, and it welcomes over 250,000 students annually through school and other organized groups, in addition to the museum's general audience and family visitors. The space at once embodies the aspirational ideals of visitor agency and the museum's ongoing shift in educational approaches. A primary goal of *Design Lab* is to provide welcoming invitations into engineering and design, and to engage visitors in solving personally meaningful problems. Museum staff knew that facilitation was key in providing visitors with approachable entry points to engage in such an open-ended experience, but what we did not know was the degree of experimentation that would be involved in developing experiences that would do this inclusively for all visitors.

Visitors encountered *Design Lab* after walking through phenomenon-based exhibits that illustrate complex scientific principles, which primed them to engage with science as observers learning from others' expertise, rather than as creators, designers, experimenters with valuable ideas of their own. *Design Lab*, on the other hand, offered open-ended activities with everyday repurposed materials, and visitors were free to decide for themselves what to create and how. The purpose of these activities was at times unclear to visitors; the idea that they could learn about engineering by *doing* it, rather than being told about it, was not intuitively obvious. And engineering design activities without context can be off-putting, unapproachable, or simply not motivating for many learners. This situation highlighted the need for the museum to provide compelling reasons for visitors to solve open-ended engineering and design problems.

We approached this challenge by *drawing on diverse areas of expertise* to bridge research and practice and develop evidence-based approaches to activity development. A recent design-based research project funded by the National Science Foundation aimed to find a balance between providing relatable contexts for engineering design projects while still leaving them open to visitors' choices and ideas. The project was grounded in prior research from across fields showing that narratives can provide personal and social contexts for engineering problems by helping learners empathize with the people for whom they are designing (Walther et al., 2017). Activity development was based on evidence that this empathic approach to engineering has the potential to open up the field to learners who tend not to be engaged by traditional engineering challenges, and particularly girls, who remain drastically underrepresented in the field (Capobianco & Yu, 2014). The project set out to create six engineering activities that used subtle hints of narrative to evoke visitors' empathy and support engagement in the engineering design process. Exhibit activity developers, researchers, and Explainers worked collaboratively to iteratively experiment with novel ways of infusing narrative elements into otherwise decontextualized engineering activities (such as designing a vehicle that could move over different surfaces, protecting something from breaking when dropped, building a stable structure, etc.). Our design-based research focused on observing the impact of narrative approaches on visitors' expressions of multiple facets of empathy (including their emotional responses to the problems they were solving, perspective-taking to imagine others' points of view, and prosocial behaviors to help others with their designs; Walther et al., 2017) and use of engineering design practices that are

advocated for in K-12 engineering education (including problem scoping, ideation, testing, and iteration; ASEE, 2020), particularly among girls ages 7–14.

Throughout this project, we used knowledge from both researchers and practitioners to understand what design decisions were supporting these aspects of visitors' engagement, and why. The authority and expertise in the project had to be distributed across the entire project team in order to balance theoretical underpinnings with practical needs on the museum floor. Staff across teams and at multiple levels contributed jointly to design decisions throughout activity development. Researchers provided some parameters for activity development based on existing research on empathy and its connections to engineering practice, and staff members in *Design Lab* used their deep knowledge of the qualities of effective and sustainable museum experiences to suggest light touch ways of layering narratives onto existing *Design Lab* activities and other classic engineering challenges.

Project leaders supported *experimentation* and *ongoing reflection* throughout the work. The development process for each of the six activities involved weekly prototyping with researchers, Explainers, and activity developers present, debriefings at the end of each prototyping day, and weekly discussions about how to revise activities based on the emerging findings. The involvement of Explainers was critical throughout the process — the project team recruited pairs of Explainers to participate in activity development for several months at a time, providing their perspectives as facilitators to guide iterative revisions of the activities each week. As Explainers became familiar with the purpose of the research, they were empowered to try out new ways of facilitating the activities to highlight and extend the narratives and support visitors' empathy as an integral part of STEM learning.

The iterative development of six narrative-based activities gave the team the opportunity to *experiment* with a range of different strategies for evoking empathy and supporting engineering practices. Scoping out the problem space and experimenting with as many ways of using narratives as possible helped the team determine what strategies we had not yet considered and think creatively about subtle changes that could have an impact on visitors' engagement. For example, we wanted to use characters that represented whom learners were designing for and why, in order to make engineering challenges more human-centered (e.g., designing something to help someone, rather than just creating something that is fast, stable, sturdy, etc.). Through iterative testing of different activities, we integrated realistic characters (pets and grandparents), and whimsical ones (aliens and space travelers), and investigated the impact of providing opportunities for visitors to personalize characters (e.g., by naming them) or invent their own (e.g., by asking them to engineer shadow puppets and tell a story with them). By being strategic in experimenting with new iterations of narrative elements, and checking our emerging findings against what we had observed and attempted in the past, the team developed and refined design principles for integrating empathy in light touch, feasible ways. For example, we found it was important to provide a hint of an evocative character or setting as a starting point, but to leave space for learners to choose or define the details of the narrative themselves, rather than overly constraining the narratives in order to narrow the engineering problems and potential solutions that learners could tackle. Because these strategies were iteratively tested and

reinforced over time, they have become a habitual part of activity development and have been integrated into other activities developed in *Design Lab* beyond this project.

Ultimately, the project team successfully developed productive ways of sharing authority, but systems and practices had to be enacted to encourage experimentation with new ideas. First, the team had to become more accustomed to doing rough prototyping with basic materials to vet initial ideas. This required *Design Lab* staff to temporarily put aside their concerns about how to make activities durable and streamlined, so that ideas could be tested and adjusted quickly. Second, research staff had to become more comfortable doing qualitative observations as activities rapidly changed, and incorporating others' observations and interpretations to round out their data. Finally, the team explicitly encouraged Explainers to respond to what they were observing and experiment with new materials or ways of facilitating. Giving Explainers permission to change their approaches, rather than attempting to rigidly control activities for data collection purposes, supported a culture of inquiry and curiosity that made it easier to generate new ideas and alternatives as a team. Though this process took longer than anticipated, these cycles of testing and discussion, in which all members of the team were on equal footing, were critical to establishing strong working relationships in which everyone felt comfortable contributing ideas and understanding each other's needs and priorities (e.g., with regard to visitors' experiences, explainer support, and research data).

Throughout the project, we also used prior research and our own observations to *guide our reflection* as a team and synthesize research findings and implications for practice across the entire set of activities. Locating each activity within a larger theoretical framework changed our ways of working together by providing a structure and common language for staff to make sense of findings from iterative tests within a larger context. The development of the six activities allowed for the team to explore a range of narrative elements that evoked empathy in different ways, and the research showed that empathy supported visitors' overall engagement and use of engineering practices among girls ages 7–14 (Letourneau & Bennett, 2020; Pepler et al., 2020). The processes for distributing authority and synthesizing knowledge that emerged in this project made engineering activities in *Design Lab* more welcoming and inclusive, and continue to influence our activity development and design-based research.

DISCUSSION

This article describes our museum's efforts to evolve away from presenting STEM with a single authoritative voice and toward grounding STEM learning in the interests and experiences of visitors, in ways that leverage visitors' prior knowledge to create points of connection. Shifts toward distributed and transformational leadership within and across projects have been critical to our successes in this effort to date. The case studies in this article illustrate how teams within our institution drew on key qualities of these leadership models: articulating an aspirational vision for the future, distributing authority and honoring individuals' diverse expertise, supporting experimentation and risk-taking, and guiding reflection to synthesize knowledge. Although these qualities were enacted in

different ways across each project, the lessons learned highlight strategies and processes that are applicable to other science centers, and museums in general, as the field moves toward supporting more visitor-centered experiences.

Empathizing with Visitors to Motivate Shifts in the Status Quo

Research on transformational leadership emphasizes that the aspirational visions that motivate organizational change must be shared and internalized in order to lead to meaningful and lasting changes (Bass, 1985). Appealing to staff on an emotional level can spark greater innovation and creativity by engaging staff in working together to achieve a shared vision (Judge & Piccolo, 2004). In the projects described here, this inspiration and emotional engagement came from seeking to understand our visitors, their needs, and their points of view — a goal that motivated front-line staff as much as educators, researchers, and leadership. Putting ourselves in visitors' shoes required embracing uncertainty about what new approaches to exhibit development might involve, and what new supports and guidance our visitors might need. Because of the diverse goals and teams involved, the role of individual charismatic leaders was less crucial in this process than building on our direct experiences to gain a vivid understanding of the challenges we were working together to address.

Even more importantly, linking this visitor-centered point of view with existing evidence about the social and situated nature of informal STEM learning — that learning is grounded in visitors' prior experiences, social interactions, and cultural practices — led us to question deeply held assumptions about what learning means and looks like in a science center, and to confront potentially harmful implications of existing practices embedded within our institutions and in the field at large. For example, when professionals in the exhibit design workshop spent time discussing their own experiences as learners, they began to notice aspects of exhibits that prioritized the perspectives of STEM experts and did not welcome visitors' own voices or perspectives. Reimagining these exhibits required leveraging practice-based knowledge and research in the learning sciences about how to create entry points for visitors to engage with STEM content in personally and socially meaningful ways. Likewise, in the *Design Lab* case study, the project team recognized that visitors needed more compelling invitations into engineering activities, and developed new approaches that used narratives to engage visitors on an emotional level and encourage them to elaborate on the problems they were solving based on their own ideas and experiences. These visitor-centered strategies have led to long-term changes in activity development and facilitation practices in *Design Lab* and throughout NYSCI.

Fostering Collaboration across Diverse Perspectives

All of our case studies involved bringing together individuals with different areas of expertise to shine a light on different aspects of visitors' experiences and collectively redefine what it means to prioritize agency in STEM learning. Researchers in transformational leadership and organizational learning have described the need for teams to find common ground when establishing and working

toward a shared vision (Avolio et al., 2009; Carson et al., 2007). In our own work, NYSCI's educational philosophy was grounded in fieldwide understandings of STEM learning in informal spaces, but translating this theoretical foundation into practice meant interpreting and operationalizing it across different areas of the museum. Each project depended on having professionals in the room who had diverse personal backgrounds, diverse professional areas of expertise, but many shared goals and priorities for the exhibits and experiences we aimed to create. This process allowed teams who might exist in separate silos to understand one another's everyday experiences and begin to develop a common language.

Nevertheless, the enthusiasm that staff shared when tackling a mutually recognized challenge sometimes foundered when an initial process of sharing perspectives and knowledge had to be translated into clear decisions for action. For example, decisions about whether to set time limits on visitors' use of *Design Lab* on high-volume field trip days became a complex discussion that touched on mission, revenue, management of facilitators, materials planning, and more, requiring us to prioritize and balance the concerns of staff across different teams in order to set institutional policies. Over time, cross-departmental teams became skilled at defining the problem to be solved and developing coordinated solutions and compromises that took multiple perspectives into account, but ensuring that broader groups of staff, including institutional leaders, were informed and bought into those decisions took more time. We continue to work to create clear pathways to make sure that educational strategy and practical needs are continually being informed by one another.

Grounding Collaborative Efforts in Theory and Direct Experiences on the Museum Floor

Researchers tracking organizational change in museums point to the importance of shifting from a culture of *teaching* to a culture of *learning* to redefine core organizational values (Hein, 2012; Hooper-Greenhill, 2007; Kristinsdóttir, 2017; Roberts, 1997). Reshaping our approach to STEM learning not only required multiple perspectives to be part of the discussion, but also required us to foster a culture in which teams were actively seeking out intersections in their ideas and expertise to guide deeper exploration and innovation. In each case study described here, using existing research and current best practices to carve out and explore a problem space was critical in guiding this process. At the same time, grounding discussions in direct observations and experiences with museum visitors revealed ambiguity in how our ideas about STEM learning might be implemented, and helped us identify areas of uncertainty to explore in more depth. In this way, projects brought together theoretical foundations in the literature and the experiences of staff at multiple levels. In addition to building on the wide-ranging expertise of staff across departments, other institutions might find new avenues for exploration via internal research-practice collaborations, external partnerships (be they with research partners or other museums), or existing theoretical frameworks related to aspects of learning that resonate with their educational approaches and design strategies. Only by having these discussions across many layers of our institutions over time can we start to build robust, shared ideas about what it means to create equitable and accessible learning experiences.

Building in Support for Iterative Experimentation and Reflection

Creating an internal culture that supports experimentation required project leaders to set expectations about how teams would learn together, model risk-taking (and even failure), and sustain repeated cycles of testing and reflection. Transformational leadership models emphasize the role of leaders in actively soliciting new ideas in these ways (Bass, 1985). Likewise, research on reflective practice points to the need for museums to examine and update their internal frameworks based on ongoing observation, experimentation, and reflection (Falk & Dierking, 2016; Kristinsdóttir, 2017; Tran et al., 2019). Our case studies show the value of putting systems in place that make experimentation an expected part of day-to-day responsibilities within and across teams. In the case studies with Explainers and in *Design Lab*, once shared goals were established, teams developed training systems, adjusted day-to-day procedures, and set aside time for reflection that became a regular part of practice. In the exhibit workshop, the design process itself provided a familiar structure for exhibit developers and educators to imagine how exhibits might be different and to experiment with new approaches. This harnessed an inherently iterative process to frame the shortcomings of exhibits as opportunities for creative problem-solving, allowing individuals with a range of perspectives to surface questions, contribute ideas, and reflect on alternatives. These examples illustrate how providing social support and guidance can reinforce and sustain efforts to shift museum practices (Vera & Crossan, 2004), and highlight the need for leaders to give staff ownership in deciding how new practices could be implemented (Carson et al., 2007).

One challenge in iteratively experimenting with new approaches, however, was the uncertainty in how visitors might respond, coupled with a desire to ensure that all visitors have a positive experience. For example, Explainers often relied on facilitation strategies that they felt confident using, and therefore needed substantial support to experiment with new entry points to STEM conversations. Likewise, putting activities that were still under development and might not “work” out on the floor in *Design Lab* felt risky because, unlike the tried-and-true activities that had been offered in the past, the benefits of the new approaches we were testing were less certain. One helpful compromise was establishing practices for setting visitors’ expectations — announcing when we are tinkering with new ideas and being transparent about the fact that we are learning from visitors’ feedback to improve the experiences we offer. Making our own learning process more visible as we iterated exhibit and activity ideas has helped us start new kinds of conversations with each other across departments, and with our visitors.

CONCLUSION

Making more room for inter-departmental collaboration and reflection has been critical to our institution’s efforts to translate aspirations for increased visitor agency into new ways of working. This took investment from private and federal funding, which allowed us to protect staff time to focus on experimenting with new methods of working cross-functionally to define and address shared questions of practice. In each of the case studies described here, distributed and transformational

models of project-level leadership were critical in our ability to create and sustain more inclusive, visitor-driven learning experiences because the collaborative work within the project teams mirrored the aspects of learning that we hoped to support for visitors — our own learning was embedded in social interactions and personal experiences from multiple points of view. Aligning shifts toward greater agency among visitors with parallel shifts among staff allowed these efforts to be mutually reinforcing, and our well-honed understanding of research and practice in the learning sciences provided a foundation for investigation and improvement of our practices.

No single effort could have achieved the shifts toward more generative forms of visitor engagement we are now working toward. It was the collective experience of working simultaneously on exhibits, activity development, and facilitation that laid the groundwork for transformational change. Nevertheless, finding sustainable, balanced approaches to this kind of work continues to be a challenge. We intend to prioritize shared decision-making, iterative design practices, and putting practice-based knowledge and research evidence into productive conversation with one another. But funds are often short, calendars are full, and timelines are tight. Our goal is to normalize and institutionalize these decentralized practices, so that even though they will never be perfectly implemented, they also will not fade away.

Together, these cases highlight the practical consequences of a paradigm shift toward supporting visitors' agency in science center spaces, and the importance of engaging teams in collectively defining and working toward these new goals in order to overcome the inertia of our existing practices and commit to institution-wide change. **END**

ACKNOWLEDGMENTS

This material is based upon work supported by the National Science Foundation under Grants No. 1712803, 1811063, 1763917, and 1634069. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation. We also acknowledge generous support from the Golden Family Foundation.

The authors wish to thank the following individuals for their contributions to this work: At NYSCI: GERALYN Abinader, Yessenia Argudo, Jelena Begonja, Dana Hemes, Drew Lauderdale, Sophia Madonia, Truck McDonald, Amelia Merker, Iboun Morrison, Satbir Multani, Leah Persram, Amanda Reed, Kristian Roopnarine, Abigail Sewnauth, Liz Slagus, Karl Szilagi, Erin Thelen, and Betty Wallingford. Collaborators at the Scott Family Amazeum: Ashlee Bailey, Sam Dean, Joel Gordon, and Mindy Porter; the Tech Interactive: Lauren Cage, Katherine Ozawa, and Prinda Wanakule; and Creativity Labs at UC Irvine: Kylie Pepler, Anna Keune, and Maggie Dahn; and Attendees from other institutions at NYSCI's exhibit design workshop: Julie Bowen, Ashley Boycher, Justin Griffith, Josh Gutwill, Paula Hooper, Elisa Israel, Manny Juarez, Katie Koffler, Jennifer Martin, Sarah May, Cheryl McCallum, Peggy Monahan, Polly McKenna Cress, Shane Montoya, Mike Ortiz, Jennifer Rehkamp, Chagit Tishler, Charlie Walter, Janella Watson, Eric Welch, Blake Wigdahl, and Pam Winfrey.

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