



Integrative approaches to dispersing science: A case study of March Mammal Madness

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Abstract

Objectives: Public engagement is increasingly viewed as an important pillar of scientific scholarship. For early career and established scholars, navigating the mosaic landscape of public education and science communication, noted for rapid “ecological” succession, can be daunting. Moreover, academics are characterized by diverse skills, motivations, values, positionalities, and temperaments that may differentially incline individuals to particular public translation activities.

Methods: Here we briefly contextualize engagement activities within a scholarly portfolio, describe the use of one public education program—March Mammal Madness (MMM)—to highlight approaches to science communication, and explore essential elements and practical considerations for creating and sustaining outreach pursuits in tandem with other scholarly activities.

Results: MMM, an annual simulated tournament of living and fossil animal taxa, has reached hundreds of thousands of learners since 2013. This program has provided a platform to communicate research findings from biology and anthropology and showcase numerous scholars in these fields. MMM has leveraged tournament devices to intentionally address topics of climate change, capitalist environmental degradation, academic sexism, and racist settler-colonialism. The tournament, however, has also perpetuated implicit biases that need disrupting.

Conclusions: By embracing reflexive, self-interrogative, and growth attitudes, the tournament organizers iteratively refine and improve this public science education program to better align our activities with our values and goals. Our experiences with MMM suggest that dispersing science is most sustainable when we combine ancestral adaptations for cooperation, community, and storytelling with good-natured competition in the context of shared experiences and shared values.

1 | INTRODUCTION

As researchers and educators, 21st Century scholars are increasingly expected to effectively disperse knowledge

beyond our academic disciplines and institutional classrooms (Habibi & Salim, 2021; Hinde et al., 2021; Hotez, 2020) in parallel with expanding expectations of research-intensive institutions (Crow & Dabars, 2015). Depending on

the activities, audience, and purpose, dispersing scholarly research can involve science communication (“SciComm”), knowledge translation, public engagement with science, public outreach, and/or informal science education (Curran et al., 2011; Esmail et al., 2020; Raban & Gordon, 2021). Funding agencies, including the National Science Foundation and the Wellcome Trust, have identified public engagement as a core aspect of research. The COVID-19 pandemic has motivated calls for the National Institutes of Health to adopt a “public engagement” criterion among their existing criteria for significance, investigator, innovation, approach, and environment (Woodruff & Woodruff, 2021). Even before the COVID-19 pandemic was declared, World Health Organization Director-General Dr Tedros A. Ghebreyesus (Ghebreyesus, 2020) identified earning public trust and building scientific literacy as vital for confronting the current “infodemic” on social media and addressing urgent health challenges in the next decade (2020).

Contributing to the public translation of our science can be deeply rewarding for scholars. Although academic writing increasingly affords opportunities for researchers to communicate aspects of ourselves, public translation affords broader opportunities to manifest our values, identities, and voices. As scholars, our professional activities are fundamentally influenced by our foundational philosophies, cultural values, and individual perspectives shaped by our lived experiences (Figure 1). To the extent that we intentionally anchor our academic portfolios to these aspects of ourselves as individuals embedded within our communities and societies, we can intentionally build and guide our research programs, curricular offerings, professional service, and public outreach in light of our personal vision and professional mission. Further, we can embrace strategies and tactics that harmoniously reflect our individual attributes, especially temperament and positionality, while developing and expanding our visualization, story-telling, and other communication skill sets (Botsis et al., 2020; Cooke et al., 2017; Hinde et al., 2021; Keller & Limaye, 2020). Tactics for dispersing our science can expand beyond the restricted audiences of conventional academia to “broadcast” approaches with the potential to reach wide public audiences (Figure 1). Indeed science communication can be a vital activity for finding meaning and purpose as a scholar in an academy increasingly characterized by conspicuous production (Alvesson et al., 2017; Knights & Clarke, 2014). Such activities may be especially resonant for scholars from historically excluded and contemporarily marginalized demographics and identities, and should be highly valued in evaluation (Schell et al., 2020). Moreover, rather than a tradeoff between research performance and public engagement, these activities can be mutually enhancing (Kassab, 2019).

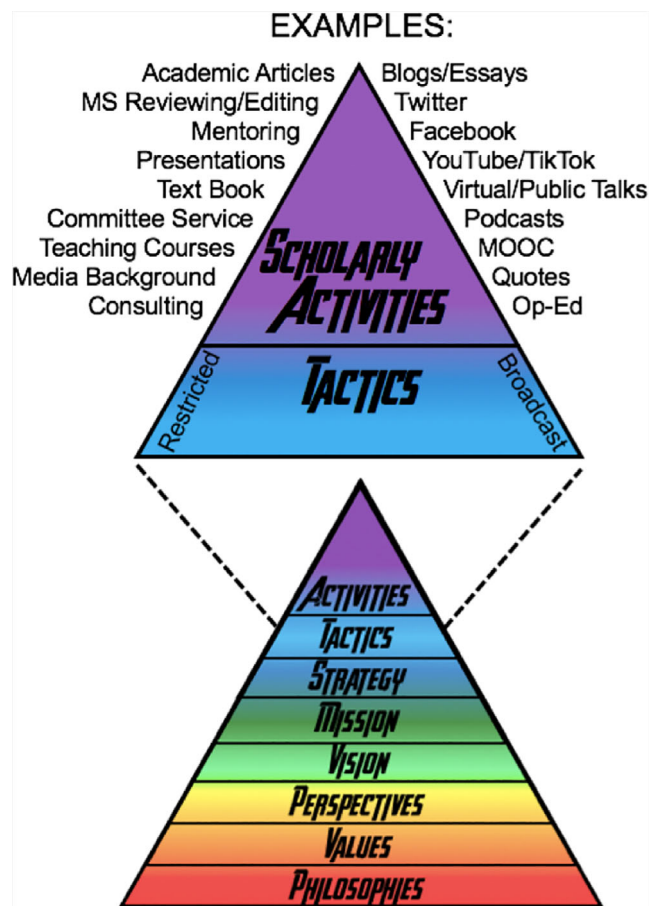


FIGURE 1 A conceptual model for intentionally developing a professional portfolio of scholarly activities that derives from philosophical foundations. Through reflexive consideration of individual values and perspectives, the scholar can develop a personal vision and mission for their career path, selecting strategies and tactics in service to their goals and in harmony with their true selves

Despite the recognition of the importance of public translation of research, identifying appropriate methods for disseminating our science remains a formidable challenge. Conceptually “our research” can refer to the specific data we collect and analyze, “updates from fieldwork” (stephanielookingup on Instagram), showcase findings from the field site (Hyena Project Ngorongoro Crater Stories Blog) and research by a broader subset of colleagues (Powered by Osteons Blog by Killgrove), highlight findings from a specific discipline (Deep Sea News Blog Collective), focus on a topic from multiple perspectives across academia (Warm Regards Podcast by Gill and Laungani), provide a guest contribution to an organizational platform (Sapiens by the Wenner-Gren Foundation) or scientific findings broadly (Raven the Science Maven on TikTok). Scholars have to select among myriad platforms to reach disparate audiences of variable motivations and craft effective messages to stimulate engagement and

facilitate learning (Canfield et al., 2020; Hinde et al., 2021; Ocobock & Hawley, 2020). Classroom visits, K-12 field trips, public presentations, and media interviews have been important, in person components of public translation of science for decades. More recently, social media and virtual platforms present new opportunities for outreach. Basics for academics about social media platforms such as Twitter, Facebook, Instagram, and TikTok, the design elements valued by user communities and the drawbacks of different platforms, have been described in detail elsewhere (Cheplygina et al., 2020; Deeken et al., 2020; Habibi & Salim, 2021; Klar et al., 2020; Mukhopadhyay et al., 2021; Stofer et al., 2020). We note though, that social media platform tools and communities can experience relatively rapid changes and research effort for the professional utility of these platforms is highly variable. Importantly, academic engagement on social media can be valuable for providing access to conferences, community, and connections for scholars who are experiencing isolation in their institutional context as a function of their research topic and/or dimension(s) of their identity (Beyene & Panescu, 2020; Kachen et al., 2021; Luo et al., 2020; Ortega, 2021; Reeve & Partridge, 2017).

Here we present one public engagement platform, March Mammal Madness (MMM) (Hinde et al., 2021), to highlight elements of public translation of science that we have found particularly effective, rewarding, and community-building that may be useful for others engaged in public outreach. A thorough description of the mechanics, history, and impact of the tournament has been reported elsewhere (Hinde et al., 2021), but here a subset of contributors are excited to contribute for this special Hackademics issue of the American Journal of Human Biology with more topical focus. Importantly, MMM has not only allowed us to publicly translate the science of our academic subfields, but we have been able to navigate our approach to the tournament specifically, and our professional activities more broadly, in accordance with our deeper philosophies and values. Moreover, our contributions to MMM are only one aspect of diversified portfolios (Table 1), that are necessary to achieve our individual goals for message, audience, and impact.

2 | MARCH MAMMAL MADNESS

Annually since 2013, the simulated, single-elimination tournament MMM, presents empirically informed, narratively delivered descriptions of what could happen during encounters among animals resulting in fatal/injurious, withdrawal, and other eliminating outcomes. After the outcomes are determined by a random number

generator, scientist-narrators then craft a play-by-play narrative of the encounter from the scholarly literature (Hinde et al., 2021). Play-by-plays of the animal “encounters” are initially delivered by scientist-narrators as though being described in real time “live” on Twitter with embedded citations and links to the scholarly literature. These tweets are subsequently organized into collections (Storify 2013–2016, Wakelet 2017–2021, Twitter 2021), “reported” by MC Marmot and the Rodent Roundtable (YouTube 2017–2021), and summarized into sports blurbs with content and links posted across multiple platforms, including a dedicated Facebook page and ASU MMM LibGuide (Perry et al., 2017). These resources are also posted directly in a shared Google Drive Folder that is directly accessible by thousands of educators (2020–2021). The creative team behind MMM includes librarians, artists, life scientists, conservationists, graphic designers, sports-writers, social scientists, puppeteers, and educators working cooperatively to develop and deliver this open educational resource in English (since 2013) and Spanish (since 2020). Many tournament materials are now archived and freely available in the ASU MMM KEEP collection (Perry & Hinde, 2020). In tandem with the tournament, since 2015 the American Society of Mammalogists have tweeted photos of tournament taxa from their photo collection and since 2017 Oxford University Press has organized an online special issue of freely available articles featuring tournament taxa.

Initially created as a lark for “Biologist Twitter,” K-12 and college educators spontaneously adopted MMM with their learners and represent the best-studied tournament users within the broader MMM community. For years, educators informally volunteered feedback via Tweets and e-mails that were discussed among MMM organizers. In 2018, we launched pretournament surveys and in 2020 added post-tournament surveys to more systematically understand how and where educators are using the tournament with their learners. From these surveys we now understand that MMM is distributed to hundreds of thousands of students ($N > 245,000$ in 2019) proportionally across geographic regions in the United States and nearly proportional across urban, suburban, and rural communities (Hinde et al., 2021). Based on educator responses and US Census information, we estimated that the tournament bracket was distributed to ~1% of all high-school students in the United States (Hinde et al., 2021). We know much less about the general public user of the tournament, but Twitter and Facebook activity and the fan-maintained Wikipedia page suggest that there is an active and engaged MMM community. As of this publication, the tournament Twitter account has $N > 25,900$ followers and Facebook page has $> 10,000$ likes. Notably, many of the contributors whose efforts create and deliver the MMM tournament

TABLE 1 Additional public translation and science outreach activities (selected) of MMM scientist-narrators and co-authors on the present manuscript

“Venue”	Audience	Format (role)	Access	Contributors
Skype-a-scientist	K-12 students, other learners	Live, virtual conversation (expert guest)	Teacher-organized; Group-organized (free)	MD, LD, MK
ComSciCon	General public	Festival (organizer)	Ticket-holders (free)	MD
TED talk	Attendees, general public	In person, recorded (presenter)	Ticket-holders (live, fee); internet (recording, free)	LD, KH
American Museum of Natural History	General public	In person (Presenter)	Workshop enrollment (fee)	KH
Cleveland Museum of Natural History	General public	In person (Presenter)	Ticket-holders (fee)	KH
Ologies; Just the zoo of us; Brains on	General public	Podcasts (interviewee)	Internet-enabled, media device (free)	LD, MK, KLL
Hominin advent calendar	General public	Digital advent calendar (creator)	Internet (free)	MK
Letters to a pre-scientist	Grade 5–10	Pen pal letters (correspondent)	Teacher-organized (free)	KLL
Camp cardiac	High-school students	In person (presenter)	Summer camp (fee)	KLL
Meet-a-scientist at the public library	Community members	In person (presenter)	Public (free)	MD
Bioanthropology news	General public	Facebook page (administrator)	Public (free)	MK
Leaders through education, action and hope (LEAH) project	Boston-area youth, underrepresented in STEM	STEM career guidance (panelist)	Student internship (paid)	MD
BABIES	General public	Documentary series (featured scientist)	Netflix subscribers (fee)	KH
Darwin Day, North Carolina Museum of Natural Sciences	Community members	Festival (volunteer)	Public (free)	MD
Girl scouts field biology camp	Girl scouts (K-12)	Camp (facilitator)	Leader- organized (fee)	LD
AAAS/DoSER science for seminaries	Seminary programs	Science curricula materials (advisor)	Institution- organized (AAAS materials free)	MK
Lincoln Park Zoo	General public	Visitor experience (ambassador)	Zoo visitors (free)	MD

Abbreviations: LD, Lara Durgavich; KH, Katie Hinde; KLL, Kristi L. Lewton; MD, Mauna Dasari, MK, Marc Kissel.

each year were initially involved as particularly enthusiastic tournament players who spontaneously volunteered their skills or positively responded to invitations/general calls to join the MMM team.

MMM has included species from across the tree of life (Chen, 2020), but one taxon is particularly well-represented—Primates. Battle narratives frequently emphasize core themes of bioanthropology, including conservation and human impacts on nonhuman primates, reconstructing paleoenvironments and paleobehavior, and how natural selection has shaped the adaptations and evolutionary trajectory of different primate lineages, including humans. The prevalence of extant and fossil primates within the

tournament reflects the compounding influence of founder effects, research priorities, and cognitive biases. Initially created by a bioanthropologist, her already existing professional networks partially shaped the expansion of the MMM Team to favor primatologists, paleoanthropologists, and anthropological geneticists. Tournament battle narratives are based on the scholarly literature, limiting combatants to taxa that have been the foci of research, which favor primates for several reasons. Primates have received significant biomedical, anthropological, psychological, and conservation research effort (Bezanson & McNamara, 2019; Schipper et al., 2008) because nonhuman primates share many genetic, neurobiological, immunological, behavioral,

morphological, and ecological attributes with humans due to shared ancestry (Phillips et al., 2014). Additionally, primate content is particularly salient to audiences because of cognitive biases for species more similar to humans and “infantile” features (Batt, 2009; Borgi & Cirulli, 2016; Castillo-Huitrón et al., 2020). The over-representation of primate taxa, however, has several benefits. Nonhuman primate taxa can be found in 90+ countries across Afroeurasia and the Americas, but 60% are threatened with extinction and 75% are experiencing population decline (Estrada et al., 2020). As charismatic fauna, primates can serve as “flagship species” in conservation and restoration campaigns (Chapman et al., 2020) which speaks to the topic area of Human Impacts in K-12 Next Generation Science Standards (NGSS). Similarly, genetics and genomics content in MMM addresses NGSS topic areas of Inheritance and Biological Evolution. Importantly, by featuring fossil hominins, MMM explicitly discusses human evolution, a typically controversial topic that many K-12 teachers elide (Pobiner, 2016).

2.1 | Primatology in MMM

Among the extant mammalian taxa featured as MMM “combatants” from 2013 to 2021, 15% have been primates ($N = 45/295$), nearly double the proportion of primate species among mammals ($N = 518/6495$, 8%; Burgin et al., 2018). Primate combatants have reached the Final Roar in 2013, 2017, and 2020 with *Gorilla gorilla* securing the championship in 2020, the first non-Carnivora or non-Artiodactyl Champion. To celebrate this victory, instead of going to Disney World, Anthropology News invited MMM Art Director Charon Henning to create a coloring page for a special summer issue (Henning, 2020). The inclusion of diverse primate species across multiple tournament years has enabled narrators to describe a multitude of primate adaptations including mating strategies, parental care, diet and digestion, foraging, predator detection and mobbing, predation, coloration, symbiosis, grooming behavior, home ranges, fallback foods, behavioral plasticity, sources of mortality, and ethnoprimateology. At times, these topics are contextualized in a comparative perspective that speaks to an evolutionary history of shared and divergent human behaviors. Scientist-narrators frequently emphasize primate conservation and the anthropogenic sources of population declines including habitat loss/degradation (*Tarsius tumpara* vs. *Macaca nigra*, 2015), the wildlife trade (*Nycticebus javanicus* vs. *Lynx pardinus*, 2015), and hunting (*Mandrillus sphinx* vs. *Ifrita kowaldi*, 2021). In recent years, scientist-narrators have discussed how wild game can be economically and nutritionally important to locals so centering community collaborations is essential

for conservation efforts to be sustainable. Moreover, scientist-narrators now intentionally use the term “game” to describe meat from wild animals, regardless of geographic location (Unigwe, 2017).

The COVID-19 pandemic elevated the urgency for public understanding of zoonotic disease transmission and public health messaging. Indeed, the 2020 tournament bracket released just hours before the public first learned of community spread in the United States at a long-term care facility in King County, WA. A round one match-up, *Gorilla gorilla* vs. *Loa loa* (a filarial nematode) provided an opportunity to discuss risk of zoonotic disease transmission in the context of ecotourism (Gouteux et al., 1989). Until shoved off the battlefield by the gorilla in the 2020 Final Roar, the gopher tortoise (*Gopherus polyphemus*) consistently outlasted opponents by SHELLtering-in-place. In 2021, audiences were left with a cliffhanger after the first round when a chimpanzee (*Pan troglodytes*) was bitten by the ultimately defeated white-winged vampire bat (*Diaemus youngi*) wondering whether the chimpanzee could now be incubating an emergent infectious disease (Villena et al., 2018). These narrative devices stimulate “spectator” speculation and the high number of scientists who participate in playing MMM typically contribute their expertise within speculative discussions. In this way, information exchange extends far beyond the “official” narration tweets of the scientist-narrators while facilitating expanded networks and more connections among scientists and non-scientists.

Tournament players often have strong taxonomic preferences shaping their bracket predictions. This is as evident for scientists as the public, especially when scientists’ study species are in the bracket. The “Of Myths and Monsters” Division in 2021 featured species whose Latin binomial or common English name made reference to mythical entities. Both *Pan troglodytes* and *Mandrillus sphinx* were in this division (along with fan-favorite and non-mammal combatant harpy eagle, *Harpia harpyja*). In the week between the bracket drop and launch of the tournament battles, speculations about a chimpanzee versus mandrill match-up, and which could possibly defeat the harpy eagle, generated intense Twitter discussions. Relative body mass, canine length, fight style, and “smarts” featured prominently in these dialogs, with one primatologist’s summation “chimpanzees are terrifying.” Battles with highly contentious fan investment exert notable pressure for scientist-narrators to deliver a play-by-play that is narratively suspenseful and concluded legitimately. Toward these ends, rich natural history descriptions are particularly invaluable for scientific story-telling (Ramsay & Teichroeb, 2019). Interestingly, the empirical literature provided no information on the behavioral interactions of wild-living mandrills and

chimpanzees, despite some sympatry in their population distributions and shared dietary preferences. In the battle play-by-play, an adult male chimpanzee accompanied by a subadult male encountered a lone male mandrill terrestrially foraging for fallen figs in a forest fragment in Gabon (Tutin, 1999). The narrative described how chimpanzees hunt monkeys, smaller than adult male mandrills, with nutritional preferences for brains (Gilby & Wawrzyniak, 2018), the larger body mass of the chimpanzee versus the larger canine size of the mandrill (Setchell, 2016), and situated an extensive, back-and-forth mutually assessing side-eye until... the chimpanzee climbed the tree to the nest of a crowned hawk-eagle to snarf some nestlings before a flying attack by the parent raptor sent the chimpanzee careening out of the tree and withdrawing from the MMM field of battle (Takahata et al., 1984). In one fell swoop, pun intended, the battle narration addressed both the likely disinclination of a chimpanzee to tangle with a mandrill and the probable outcome of a chimpanzee encounter with a harpy eagle. A disappointing outcome for many players that even chimpanzee researchers acknowledged was grounded in realism (Figure 2).

2.2 | Paleoanthropology in MMM

Fossil taxa have frequently been featured in MMM in dedicated divisions (Fossil Mammals 2014; Antecessor 2018) or in adaptation-centered divisions of extant and fossil species (Sexy Beasts, 2015; Of Myths and Monsters 2021). Even more than among extant mammals, fossil primates are notably featured here ($N = 8/35$, 23%) with 50% of these species being hominins ($N = 4$; *Australopithecus afarensis*, *Australopithecus sediba*, *Homo neanderthalensis*, *Homo floresiensis*). MMM narratives about fossil primates have generally been contextualized within method and

theory in paleontology for reconstructing species' paleobiology, paleoenvironments, and paleoclimate (Cohen et al., 2016). In 2014, to introduce the Fossil Mammal Division, and first MMM paleo-combatants, the scientist-narrator provided introductory tweets on the comparative method (Harvey & Pagel, 1991) to explain how paleontologists infer or reconstruct behavior and body size in extinct taxa (e.g., Ross et al., 2002). Battles featuring fossil hominins have highlighted adaptations to body size dimorphism, diet, brain size, tool use, and locomotion. Using known associations between suites of skeletal features and, for example, locomotor behavior in extant species, we can infer the likely locomotor mode of extinct taxa that share those suites of skeletal features (e.g., Bock & von Wahlert, 1965). Similarly, aspects of locomotor function can be inferred in fossil taxa from mechanical models based on principles of performance optimization (Benton, 2010). For example, when two fossil hominins battled in the Wild Card (*Australopithecus afarensis* vs. *Australopithecus sediba*, 2014), the play-by-play was constructed based on their differing skeletal adaptations to locomotion. *A. afarensis* exhibits forelimb adaptations to arboreal locomotion and we used those behaviors to demonstrate how it could have defeated *A. sediba* by leveraging arboreality to gain "the high ground." Battle narrations can also explain key themes of community ecology. The 2018 encounter between the giant "sloth lemur" *Archaeoindris fontoynontii* and *Pseudaelurus quadridentatus*, an ancestor of both modern felids and the saber-toothed cats (Antón, 2013) allowed explanation of how an animal with no natural predators is vulnerable to an invasive species.

Within the tournament, protracted story arcs are common that allow narrators to scaffold knowledge with the audience. In 2017, a Neandertal hunting party "battled" as a team, progressing from round-to-round despite occasional injuries and fatalities of party members, incorporating numerous empirical findings about *Homo neanderthalensis*. Battle narrations covered Neandertal landscape use (Daujeard et al., 2012), dietary breadth (Yong, 2017, March 8), spear-wielding (Villa & Soriano, 2010), self-medication (Hardy et al., 2013), recovery from serious injury (Tilley, 2015), and use of cave bear bones (Abrams et al., 2014). In the battle narration for the Neandertal hunting party's encounter with a mythical Greek Sphinx, they were motivated to collect her massive 5-foot wing feathers, larger than the typical wing feathers they extracted from raptors and corvids (Finlayson et al., 2012). Upon the Neanderthals' approach, the Greek Sphinx posed her riddle "I never was, am always to be. No one ever saw me, nor ever will. And yet I am the confidence of all, to live and breathe on this terrestrial ball. What am I?" COULD THE NEANDERTALS ANSWER?! Here we were able to narratively tackle debates about Neanderthal language capacities and



Kris Sabbi, PhD
@KrisSabbi

...

I love chimpanzees, they're as fierce as adults as they can be sweet as youngsters... And as much as I want to say this would *never* happen, it's actually a totally plausible storyline. 🤔 Don't @ me. Lol.



Dr. Katie Hinde @Mammals_Suck · Mar 22
MANDRILL OUTLASTS CHIMPANZEE!!! #2021MMM
[Show this thread](#)

10:24 PM · Mar 22, 2021 · Twitter for Android

FIGURE 2 Dr. Kris Sabbi, researcher on the Kibale chimpanzee project, comment quote-tweeting the 2021 sweet 16 "Chimpanzee versus Mandrill" battle outcome tweet

cite new findings on the genetic underpinnings of larynx function released the day before the MMM battle (Gokhman et al., 2017). Moreover, the Neandertal story arc allowed good-humored, public bickering between scientist-narrators about the “correct” spelling of the colloquial name—Neanderthal versus Neandertal (Alex, 2016), a tongue-in-cheek disagreement that not only persists in this paragraph, but reflects the published scholarly literature (Weaver et al., 2007).

Battle narrations not only incorporate published findings, but routinely highlight understudied topics as well as gaps in the fossil record that complicate interpretations. For example, a paucity of specimens can hinder behavioral reconstruction in fossil species. The Pleistocene ape *Gigantopithecus blacki* is known only from isolated dentition and mandibles; there are no postcranial specimens assigned to this taxon. Based on the immense size of the dentition, the body mass of *G. blacki* has been estimated as 200–300 kg from hominoid regressions of molar size on body mass (reviewed in Zhang & Harrison, 2017). In 2015, *Gigantopithecus v Phascolarctos cinereus*, the battle narration included how in the absence of sufficient fossil evidence, some morphometric and behavioral inferences remain somewhat tenuous. In this way, we aim to showcase that the scientific endeavor is an iterative process and perhaps inspire the next generation of aspiring scientists to pursue unanswered questions.

2.3 | Genetics and genomics in MMM

In 2016, Prof Anne Stone established an ongoing genetics theme within MMM. The genetics team contributes tweets with evolutionary, genetics, genomics, and phylogenetic facts about each year's combatants, in parallel to the main battle play-by-play tweets. Featured content includes the genetic basis of local adaptation in primates, the impact of human activities on the genetic diversity of natural populations, and the recovery of DNA molecules from unusual sources such as feces, museum specimens, and bones. For instance, in 2018 (*Pseudaelurus quadridentatus* vs. *Archaeoindris fontoyontii*) MMM featured an ancient DNA article about extinct sloth lemur genera, where phylogenetic relationships among extinct and extant lemur species were reconstructed (Kistler et al., 2015; Karanth et al., 2005). Topics such as “ancient DNA” have a strong public appeal and often spark public engagement, and tournament players interact with these tweets with questions or comments.

MMM genetics tweets also feature articles about the molecular basis of primate traits, often contextualized into known primate phylogenies. For instance, work featured in 2020 (*Gorilla gorilla* vs. *Pristis pristis*, *Elite Trait*,

2020) shows how the analysis of the genetic variation in the *FOXP2* gene across great apes can offer insights into the evolution of communication in primates (Staes et al., 2017). *FOXP2* is associated with human language disorders and it is thought to be involved with the evolution of speech and language in humans (Enard et al., 2002). A recurrent theme within MMM genetics tweets is the distribution of trichromatic vision in primates and the genetic variation in genes coding for opsin proteins (light-sensitive proteins involved in vision) across the tree of life. In 2021 alone, the genetics team's tweets featured five different articles on opsin genetic variation, one on primates (including that year's combatant, the red ruffed lemur, *Varecia rubra*) and others on non-primate species, such as fish (e.g., the dragonfish) and even in the eyeless *Hydra vulgaris* (Cnidaria). Together, these tweets highlight characteristics and genes that humans share with other species—primates or not—shedding light onto the evolutionary fact of common descent among primates in particular and across the tree of life more generally.

When crafting genetics tweets, the genetics team follows similar strategies to that of the scientist-narrators. Tweets include hashtags, accessible language, an image (reproduced from cited literature), and a peer-reviewed article (often from open-access sources). Relevant genetic information about a given combatant is summarized in a single tweet posted in orchestration with the principle battle narration. This format allows players to quickly interact with the genetics content and, at the same time, follow the battle narration. Cited literature includes diverse themes within genetics and genomics, including classic karyotype studies from decades ago to more recent next-generation sequencing studies. Since tournament combatants are selected from all continents, genetics tweets often feature scientific research done by local scientists, amplifying the work of scholars from outside the United States and Western Europe.

2.4 | Improving MMM

Each year, the creative team behind MMM has endeavored to refine and improve the tournament in multiple dimensions responding to formal and informal feedback, adopting better accessibility practices, and addressing legacies of exclusion within society, academia, and STEM communities. These efforts have been ongoing and team members are committed to a growth mentality, recognizing that we have at times made mistakes, perpetuated biases, and neglected essential priorities. In 2016, our “MMM Standard Operating Procedures” were transformed from oral tradition to a written, annually updated



document that formally guides official tournament tweets, roles, and priorities, in combination with detailed explanations for procedures and recommendations.

Initially focused on celebrating mammals and the natural world, with sub-themes of conservation priorities and acceptance of evolutionary theory, the tournament has expanded elements to support more general scientific literacy and knowledge connection. Each year, combatant taxa are selected in consideration of taxonomic diversity, global representation, and ecosystem breadth and featuring a mix of familiar and unfamiliar species (Hinde et al., 2021). ASU Librarian Anali Perry's curation of reliable, freely available internet resources into a dedicated online Library Guide updated annually (Perry et al., 2017) enhances player navigation of the mosaic digital information landscape (Hinde et al., 2021). Scientist-narrators often cite and link scholarly publications, but even gold-standard open access articles are situated "behind a paywall of jargon" (Hinde et al., 2021), so narrations routinely also link to publicly accessible, responsibly described media coverage of research findings. Given the large number of educators and learners using the tournament, scientist-narrators are encouraged to cite and link to articles in "Frontiers for Kids," an innovative Open Access journal in which scientific findings are made accessible to younger learners through effective language and illustration with oversight from kid editors and kid reviewers. Organizers design divisions to illustrate different selective pressures, species naming practices, and build bridges to the fields of humanities (Hinde et al., 2021). For example, some divisions are organized around adaptations shaped by the environment (Marine Mammals, 2014; Desert-Adapted Mammals, 2017), or adaptations in relation to social organization (Social Mammals, 2014) or sexual selection (Sexy Beasts, 2015). Divisions have been organized for animals in relation to parts of speech. For example, Adjective Mammals in 2017 featured species whose notable physical and/or behavioral characteristics, like the screaming hairy armadillo, were embedded in their common English names. Similarly, Mammals of the Nouns in 2016 dignified taxa named for their habitat. The humble rock hyrax and modest volcano rabbit were thereby humorously restyled into Hyrax of the Rock and Rabbit of the Volcano. Heraldry was involved. In 2015, we built connections to the Humanities through a Division of Mythical Mammals from around the world (and antiquity) and inversely in 2021, divisions of real animals named for myths and monsters (Sea Beasties; Of Myths & Monsters). To facilitate more effective integration of the tournament with NGSS, MMM introduced basic science lesson plans in 2018 to be used in tandem with the tournament and added advanced AP Biology permutations in 2019. In

2020, we introduced Language Arts and Visual Arts lesson plans in harmony with expanding efforts to integrate the arts and the sciences to improve learning (STEAM: Science, Technology, Engineering, Arts, and Math; Conner et al., 2017).

Within the tournament, intentional practices have been adopted to expand involvement and participation in consideration of accessibility and inclusivity. Following a request from a science teacher at a school for deaf children, MC Marmot and the Rodent Roundtable have added closed captioning to their YouTube videos since 2019, and closed captioning is now retroactively available on their 2018 and 2017 content. Since 2021, the tournament has provided a screen-reader compatible version of the bracket and in 2021 added a large print version of the bracket. In 2020, scientist-narrators began to adopt the practice of describing animated gifs within the tweet text and in 2021, alt-text was often added to images embedded in tweets. Moving forward, expanding the creative team to include contributors dedicated to generating alt-text will improve our delivery of this important component of science outreach. Starting in 2020, the tournament bracket and science lesson plans were translated into Spanish by Prof Alejandra Nuñez-de la Mora, and translating the arts lesson plans in 2021. Language translation is only a small first step, and moving forward MMM needs to substantively incorporate content that is culturally relevant beyond the United States to more effectively engage diverse audiences (Márquez & Porras, 2020). Inclusion is not just presence or participation, but co-production, and as such collaboration during development and redevelopment. The praxis of "*Nihil de nobis, sine nobis*" (Nothing about us without us) can be reimaged for public outreach as "nothing for us without us." Such collaborative approaches serve in myriad ways, not least of all for avoiding the supremely ineffective deficit model approach to SciComm (Hinde et al., 2021; Varner, 2014). For inclusive science communication, community involvement is integral to the development of programs and activities that stakeholders will find relevant (Massarani & Merzagora, 2014).

We have actively designed tournament elements toward justice agendas. Inclusive science communication has become an important aspect of SciComm, growing into an intentional community of practice around a specific set of ideals. These goals include the recognition of historical oppressions, discrimination, and inequities, to centering the "voices, knowledge, and experiences of marginalized individuals and communities in STEMM dialogue" (Canfield et al., 2020). In efforts to decolonize science, battle narrations routinely highlight traditional names and knowledge of combatant taxa. Within the battle narration, scientist-narrators situate the battle in a

specific location, and for settler-colonial states, often identify Indigenous and traditional stewards of that land. Within the tournament game structure (Kalogiannakis et al., 2021), early rounds favor the better-ranked species and the “battle” occurs within their home habitat. However, in the Elite Trait, the Final Roar, and Championship the battle can take place in any one of four previously announced ecosystems. In 2018, one of the possible ecosystems was the hydrogeological formation “tinaja,” water-filled rock basins. Tinaja was selected because one of the highest densities of these formations occurs within Bears Ears National Monument in the American Southwest, a region of great spiritual and cultural significance to the Navajo Nation, Hopi, Ute, and the Pueblo of Zuni. Four months before the 2018 MMM tournament, a presidential proclamation reduced the protected area by over 85% and was immediately challenged by consolidated federal lawsuits from a coalition of plaintiff Tribes, conservation organizations, and a corporation. When battles were situated at tinajas, narrations showcased the cultural and environmental significance of the Bears Ears landscape and directed player attention to the concurrent legal case and ways to support protection efforts.

MMM has additionally used aspects of the tournament to confront sexism, industrialism, and racism. A battle between the mythical Greek Sphinx and Ratoskr served as a discussion of Yet Another Mostly Male Meeting #YAMMM (Eisen, 2016) when the Norse squirrel god maliciously gossiped about how Egyptian Sphinx “organized a symposium on humanoid lions & only invited males!” because “stag parties linger” (Isbell et al., 2012). In the narration, Greek Sphinx and Ratoskr then went back and forth discussing anthropomorphized lions in material culture including Maahes, Bastet, and Sekmet (ancient Egypt), Apedemak (ancient Nubia), Narasimha (Hinduism), Manticore (Persian), and Apsasu (Mesopotamia), among others. Scientist-narrators highlight global warming, ecosystem deterioration, and habitat destruction due to extractive capitalism and links between many invasive species within the continuing legacies of imperialism and settler-colonialism. At times, scientist-narrators explicitly contrast industrialized practices with thousands of years of sustainable land management by Indigenous communities (Ellis et al., 2021). Our annually updated MMM FAQ cautions players to not appropriate “totem animal” or use digital Blackface, with links to explanatory essays on these topics. Many of these elements have been adopted into the tournament due to MMM team members attentiveness to broader online conversations on justice, inclusivity, and equity as well as feedback from user communities. In this iterative process, community involvement and co-creation are two very essential components of decolonial “praxis.”

While expanding tournament content and adopting new practices are important elements of improving MMM, reflexivity on exclusionary elements are also essential for better science outreach activities. For example, in 2015 while aiming to disrupt Eurocentric classical mythology by additionally featuring mythical combatants from diverse cultures, we featured mythical combatants without verifying that such use of cultural mythology was appropriate and welcome or was appropriating and disrespectful. Similarly in 2021, Sea Beasts and Of Myths and Monsters Divisions featured species whose etymology derived from mythology. Some Latin binomials alluded to local traditional mythology, and review of the holotype description and media coverage did not report to what extent Indigenous communities collaborated in the assignment of their languages and cultural mythology to these taxonomic designations. Within Eurocentric academic worldviews, there is a prioritization for open data, transparent information, and knowledge as a public good; but these cultural attitudes are not universal and rather rest on a “specific epistemological position” (Bacevic & Muellerleile, 2018). In contrast, some philosophical worldviews consider knowledge as protected, earned, and emplaced, and accepting the validity of these philosophical views is especially important for decolonizing science (see Tsosie et al., 2021). Similarly, white, Eurocentric approaches to science education and science communication are compromised by overlooking other experts and other practices, undervaluing other knowledge, and thereby missing opportunities and audiences (Finlay et al., 2021). Another major deficiency of the MMM model is that the game structure is such that when predicting outcomes, the probabilities are based on an individual combatant that represents a prime competitor of the species. For mammals, this means that featured combatants are most typically males due to differences in sexual selection pressures and asymmetry of parental effort within our Class (but “YAY LAC-TATION!” -KH). This perpetuates male-centered biases. Broader taxonomic inclusion beyond mammals has allowed us to showcase species in which females are larger and more badass than males (e.g., green anaconda, harpy eagle) but more intentional and sustained efforts are needed.

Effective, value-based science outreach requires substantial planning to effectively engage in collaborative discussions with intended user communities, adequately develop skills and materials, and to hopefully guard against unintended messaging. As scientists, to the extent that our dialogues about our areas of research are with like-minded scholars, we can often acquire some tunnel-vision in how we think and talk about our science. A tournament of simulated encounters of animal



TABLE 2 Key considerations for developing and allocating effort toward public translation of science

Take-away	Description
Identify goals	<ul style="list-style-type: none"> -Establish immediate, intermediate, and long-term goals for your SciComm campaign/portfolio so that plans are roadmapped, opportunities are embraced, and growth is informed by a broader vision -Appreciate that “having fun and strengthening community” is a worthwhile goal that can be instrumental for personal and professional resilience
Assemble a team	<ul style="list-style-type: none"> -Welcome and recruit motivated, talented, skilled, and enthusiastic contributors who enhance, extend, and augment the capacities, reach, delivery, and impact of the campaign -Encourage connections, mentor skill development, provide guidance, share opportunities, and celebrate accomplishments among team members
Know the audience(s)	<ul style="list-style-type: none"> -Sustain bi-directional interaction with audiences to better learn and understand their interests, knowledge, misconceptions, motivations, priorities, and perspectives -Be engaged, or embedded, within the community to enable scientists to build trust, develop mutual respect, and learn from community members -Avoid ineffective, deficit-based approaches to SciComm -Reflect, and seek feedback, on whether your target audience(s) is served in a way that expands participation in science or perpetuates disparities and exacerbates inequities -Recognize positionalities, historical legacies, and contemporary sociopolitical contexts -Invite stakeholder co-production
Hone the message	<ul style="list-style-type: none"> -Improve communication approaches through evidence from pedagogical research of formal and informal learning, the value of story-telling and gamification, and the necessity of creative, artistic, and humorous elements -Use inclusive science communication practices; reject exclusionary, marginalizing, and “otherizing” messaging -Develop guiding resources for users and protocols for team members
Assess and reassess the effort	<ul style="list-style-type: none"> -Measure traffic, stakeholder and user experiences, learning and attitudinal outcomes -Invite user ideas, suggestions, and critiques and refine accordingly, to manifest “descent with modification” to the extent favored -Generate information for grant proposals, funding reports, manuscripts, annual evaluations, and job applications -Consider the benefits, opportunity costs, and tradeoffs for engaging in this work, periodically
Remember the Purpose	<ul style="list-style-type: none"> -Ensure efforts contribute to a personal and/or scholarly mission in harmony with one's own vision, values, and philosophies

combatants is all well and fun, until one considers the political implications of animals as national symbols. In MMM, combatant species are typically selected months in advance to facilitate artwork, background research, and pre-season hype. However, in 2019, when *Panthera tigris* and *Capra falconeri* were included in the tournament because of their adaptations for saltation in the Jump Jump Division, geopolitical events unfolded to our great consternation. Lesson plan materials were already distributed to educators when border tensions between India and Pakistan precipitously escalated into airstrikes. At this point, an organizer recollected that the Bengal tiger and the markhor are the national animals of India and Pakistan, respectively. Fortuitously that year, outcomes of match-ups had already been determined and we knew the tiger and markhor were not slated to battle. This near miss of a political morass demonstrates the importance of thinking carefully about the potential for unintended messaging in science outreach. Moreover,

large collaborative teams do not just mean “many hands, lighter loads,” but that there are many diverse perspectives brought to bear during discussions and planning. The numerous contributors to MMM have been instrumental for sustaining a monumental annual undertaking.

2.5 | Growing science outreach

MMM is only one example of public engagement within a species-rich ecosystem of science communication. Within the scholarly literature, key primers guide decision trees for scholars developing SciComm campaigns (for example see Cooke et al., 2017; Lundgren et al., 2020) while others highlight the difficulties in training scholars in SciComm (Baldwin-SoRelle & Swann, 2020; Rubega et al., 2021). Lundgren and colleagues (2020) recommend the “SMARTER” mnemonic

for goal-setting when launching an outreach campaign or agenda. SMARTER—Specific, Measurable, Attainable, Relevant, Timebound, Effective, and Rewarding (Rubin, 2002)—facilitates a goal structure that informs the design, incorporates assessment tools, and embeds reflection of effort to reward ratios. In 2017, Cooke and colleagues prepared a thorough 16-point guide, expanding topics to include how SciComm improves our science and the always important “don’t let your colleagues stop you.” One constant consideration among all guides is “know your audience(s).” Many outreach efforts use established K-12 learning institutions such that SciComm unequally focuses on children and teenagers (Ecklund et al., 2012). Adult learners, however, are an incredibly important demographic for establishing public trust and science literacy, generating social acceptance of scientific findings, and enhancing public support of research funding (Kappel & Holmen, 2019; McClain, 2019). Critical assessments have expressed concern that SciComm as currently practiced is not inclusive, missing intentionality, reciprocity, and reflexivity (Canfield et al., 2020; Canfield & Menezes, 2020; Streicher et al., 2014). Importantly, public engagement should not be scientists centering themselves while reaching out, but facilitating a climate and developing a conversation that enables diverse publics to “reach in” to share knowledge and participate as co-creators (Bader et al., 2018). Our experiences in MMM, and elsewhere, very much corroborate this guidance (Table 2).

In 2022, MMM will celebrate the 10th annual simulated tournament, an exciting milestone never imagined by the original founder in 2013. By embracing reflexive, self-interrogative, and growth attitudes, the MMM team has been able to iteratively refine and improve this public science education program to better align our activities with our values and goals while expanding the user community. Our experiences with MMM suggest that dispersing science is most sustainable when we combine ancestral adaptations for cooperation, community, and story-telling with good-natured competition in the context of shared experiences and shared values (Hinde et al., 2021). We encourage our colleagues to center the fun and community in their public translation and science engagement efforts.

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Carlos Eduardo Amorim: Data curation; investigation; methodology; writing - original draft; writing-review & editing. **Mauna Dasari:** Data curation; investigation; methodology; writing - original draft; writing-review & editing. **Lara Durgavich:** Data curation; investigation; methodology; writing - original draft; writing-review & editing. **Marc Kissel:** Investigation; methodology; writing - original draft; writing-review & editing. **Kristi Lewton:** Data curation; investigation; methodology; writing - original draft; writing-review & editing. **Tisa Loewen:** Writing - original draft; writing-review & editing.

DATA AVAILABILITY STATEMENT

Datasets associated with the annual March Mammal Madness tournament for science education and outreach are available in the ASU Research Data Repository (<https://dataverse.asu.edu/dataverse/MarchMammalMadness>) with additional public materials curated in the ASU KEEP March Mammal Madness Collection (<https://keep.lib.asu.edu/collections/248>)

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