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Oh, the Places We Learn! Exploring Interest in Science at Science Fiction Conventions

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ABSTRACT

Science fiction conventions are places where individuals with an interest in diverse genres and mediums can engage with a community that bridges the world of science fiction and fact. Many of these conventions provide a science "track" where science experts share their expertise and research on scientific findings and applications of science with science fiction enthusiasts. This study explored science fiction conference attendees' (n = 241) interest in science, as well as how attendees (n = 172) plan to utilize science shared at science track sessions. Survey responses were analyzed within "STEM career" groups by comparing science track and non-science track attendees, and documenting what science track attendees plan to do with the information gained at a science track session. There were no differences in how science track attendees and non-science track attendees with STEM careers reported their interest in science. For the attendees that did not report having a career related to STEM, science track participants reported higher interest scores than non-science track attendees. Over half of the science track attendees (66%) shared they will apply what they learned from a science track session to their own personal context. Furthermore, the demographics of the survey respondents may suggest that science fiction conventions are an untapped science learning environment connecting to a younger, more diverse community. Overall, recognizing the benefit of science fiction conventions is crucial to provide spaces for accessible venues of science communication to foster an interest in science for a diverse, public audience.

Keywords: science fiction, informal science education, science interest, adult learning

Introduction

Science fiction conventions are spaces where individuals can engage with a community that bridges the world of science fiction and fact (Obst et al., 2002). These conventions allow individuals who enjoy interacting with science fiction through diverse mediums (literature, TV, movies, etc.) to collaborate within the science fiction community with experts and fellow enthusiasts. Historically, the first science fiction community gatherings were documented in the 1930s, and attendees of these

informal assemblies were often white male science fiction writers (Roberts, 2006). In 1939, the first World Science Fiction Convention was held in New York (Gooch, 2008; Roberts, 2006). According to Bacon-Smith (2000), since the inaugural science fiction gatherings in the 1930s, attendance at science fiction conventions has grown over the decades, connecting a community of science fiction enthusiasts together. Conventions today range in size from small, local gatherings to large international events, such as San Diego Comic Con with 130,000 or more fans in attendance (Biagi, 2021). Overall, the purpose of these conventions is to offer an opportunity for individuals to gather in a social setting and explore multiple dimensions of science fiction or fantasy genres.

Traditionally, many of these science fiction conventions have multiple "tracks" of programming centered on different aspects of science fiction fandom, including costuming, art, video programming, readings, autograph sessions, children's activities, and special guests, often with continuous, 24-hour programming (Bacon-Smith, 2000). Most established science fiction conventions are focused primarily on fictional literature, but have grown to include television, film, comics, video or computer games, board or card games, and animation. These conventions are largely fan developed, often not-for profit, and consist of various programming options, all connected to the world of science fiction and fantasy. In essence, one becomes completely immersed in the fan experience, often spending days at the larger conventions where participants cosplay (dress in costumes). While the focus of all these conventions is on science fiction with a core of similar programming, most conventions have a unique theme with differences in duration, session options, and activities (Dragon Con, 2021; Biagi, 2021).

Many of these conventions provide "science track" sessions in which science professionals share their expertise and research on scientific findings and applications of science related to science fiction and fantasy with fans. The nature of these science-based sessions is wide and varied. Some sessions directly connect to specific genres (literature or media) and are structured with individual speakers and panels, while other sessions are more interactive. Common science track experiences may include film viewing, stargazing (virtual or in-person), hands-on activities, and interactive robotics experiences (Dragon Con, 2021). Topics can be expanded to include trends in education, socio-scientific issues, and recent advances in all fields of science (Slater & Slater, 2019). For the context of this paper, a science fiction convention is defined as a gathering of individuals who participate in the culture and fandom related to an array of science fiction and fantasy genres.

Because of the growing popularity of these events and the varied backgrounds and interest of attendees at science fiction conventions, a more comprehensive picture is needed to document attendees' interest in science and what, if any, is the impact on behavior or actions after attending science track sessions. The science track sessions offered at many science fiction conventions are spaces dedicated to the learning and exploring of science. These sessions may assist in addressing issues related to interest in science, scientific literacy, and science communication in public venues, as there is a need for "creative and innovative strategies" in providing science learning opportunities to the public (Monzack & Zenner Petersen, 2011).

As suggested by the National Science Teaching Association (2012) and the National Research Council (NRC, 2009), informal learning environments, such as science sessions at science fiction conventions, are critical for individuals to develop interest in science, beyond the traditional, formal learning environment. This study sought to compare interest in science between those individuals who attend science track sessions and those who do not attend science track sessions at a science fiction convention. The comparison of science interest among attendees were further examined within STEM career groups as prior research may suggest that individuals with a STEM career may have a higher interest in engaging in science-related informal learning experiences (Jones et al., 2019). Secondly, this study documented what actions or activities science track attendees plan to take, using the information learned or shared at a science track session based on the Contextual Model of Learning (CML) framework. How individuals process and act on science learned in informal settings can provide

insights into how comfortable they are crossing borders into the culture of science (NRC, 2009). This information may allow planners, researchers, and educators insight into the public mindset regarding science, help them utilize these accessible venues of science communication, and consider other out of the box ways to foster an interest in science. The research questions guiding this study are described below.

> RQ1: Are there differences between science track and non-science track attendees' (within STEM career groups) interest in science?
>
> RQ2: How do science track attendees utilize the information provided at a science track session?

Review of Literature

Entrenched within current events and policy related to science, technology, engineering, and mathematics (STEM), experts are calling for the need to have a scientifically literate populace and the development and perseverance of STEM career professionals (Priest, 2014; Rosenzweig & Wigfield, 2016). However, fostering both student and public interest and knowledge in STEM-related learning experiences and careers has been problematic, as indicated by national test scores and shortage of diverse professionals in the STEM workforce (Ball et al., 2017; Cannady et. al, 2014). Aikenhead (2001) suggests that "Science can be thought of as a culture with its own language and conventional ways of communicating" (p. 24). Feeling comfortable in the culture of science for all individuals participating in STEM informal learning events may be dependent on understanding that language, as well as the customs, norms, and values of science. Because of the unique language, customs, and skills involved in understanding science, participating in the culture of science can be difficult for the public.

Furthermore, there are barriers that result in non-participation in science learning events, spurring concerns that some of these events may not be equitable. Some of these concerns include accessibility of the event (e.g., infrastructure and associated costs), communication and relationship building between the science event organizers and the community, and acceptance and celebration of groups who may have been excluded from similar events in the community's past (Dawson, 2014; Hite et al., 2019). As equity and access are complex issues, engaging with the public via science learning experiences related to specific contexts (i.e., science fiction conventions and fandoms), may create learning spaces that value diversity and inclusion and connections to the public's personal interest, such as science fiction, to science.

To address these issues, researchers have suggested that in order to support learner interest in science, motivation must be fostered to help the public feel more comfortable in the culture of science (Aikenhead, 2001). Science and STEM learning opportunities should be available through informal learning contexts that support science communication, learning, and literacy (Aikenhead, 2001; Schwan et al., 2014; Stocklmayer & Rennie, 2017). When science communicators participate in public activities, people feel more at ease in the culture of science (Aikenhead, 2001). Informal learning environments may support social interactions between learners and science experts and promote interest and motivation in science or STEM careers; this includes museum and science centers (Martin et al., 2016), summer science camps (Kong et al., 2014), science festivals (Jensen & Buckley, 2014), science cafés (Childers et al., 2022), STEM-related hobbies (Jones et al., 2017), and citizen science projects (Jones et al., 2018). Science fiction conventions, situated as unique informal learning environments, may also contribute to addressing the need to promote science and border crossing into the culture of science.

Science Fiction and Education

Science fiction is a bridge between human imagination and scientific discoveries. The term science fiction has a myriad of definitions because of the complex nature and breadth of the genre (Roberts, 2000). Generally, science fiction has been described as imaginative fiction, scientific fictionalizing, a thought experiment, and metaphorical but metonymic (Broderick, 1995; Jones, 1999; Roberts, 2000; Suvin, 1979). Science fiction, as a genre, can influence public thought and opinion as well as question the affordances of scientific endeavors (Menadue & Cheer, 2017). Furthermore, science fiction can capture an audience's imagination and spark creativity and ingenuity, enabling science experts to create unique opportunities to connect science fiction and science fact with the public (Menadue & Cheer, 2017). Science education and communication, framed by science fiction, may be a conduit to increase interest and understanding of science as the public is lured into the culture of science.

The field of science fiction has gained traction in education instructional practices and curriculum to teach science concepts through the lens of fan fiction such as movies and comics. The use of science fiction in classrooms enables learners to build critical thinking skills and support interest and positivity towards reading (Vrasidas et al., 2015). Saunders et al. (2004) suggested that curriculum designed to capture learners' imagination may recruit a diverse group of learners and promote novel approaches to teaching. Additionally, Cavanaugh (2002) shared that the value of science fiction entertainment media supports student interest and learning in science. There are multiple examples of lesson plans and ideas shared by educators exploring the concept of utilizing science fiction in the classroom to teach science in content areas using science fiction films and shows (Barnett & Kafka, 2007; Cavanaugh, 2002; Dubeck et al., 1993; Laprise & Winrich, 2010; Stutler, 2011), comics (Matuk et al., 2019), literature (Berne & Schummer, 2005; Czerneda, 2006; Liberko, 2004; Oravetz, 2005; Singh, 2014; Vrasidas et al., 2015), and through a variety of science fiction media (Allday, 2003; Bixler, 2007). Science learning through the integration of science fiction in formal classrooms has been used as a tool to support student interest in science; however, it has been suggested that there may be cultural and gender biases that may limit female interest in science if fiction is utilized as a learning tool in formal learning spaces (Hasse, 2015).

Science Fiction Conventions as Informal Science Learning Experiences

Outside the context of formal education learning spaces, there are informal spaces to learn science at science fiction conventions. Similar to science cafés (Childers et al., 2022; Dijkstra, 2017; Norton & Nohara, 2009) and science festivals (Jensen & Buckley, 2014; Rose et al., 2017), engaging science-themed spaces and activities, such as science fiction conventions, have increased in popularity and access for the public. These conventions provide educational opportunities to learn from science experts about current and future trends in scientific research, and the science fact in science fiction, in addition to a variety of sessions dedicated to the fictional aspects of the genre (Slater & Slater, 2019). The science tracks at these science fiction conventions are a type of informal learning experience, specifically designed to engage the public in science. According to the National Research Council (2009), "informal environments are generally defined as those including learner choice, low consequence assessment, and structures that build on the learners' motivations, culture, and competence" (p. 47). These science tracks meet all the criteria for an informal learning environment as characterized in the 2010 report by the National Academies of Sciences (NRC, 2010). See Table 1 for information on the alignment of the characteristics for an informal learning environment as described by the National Academies of Sciences (NRC, 2010) and the science tracks found at science fiction conventions.

Table 1

National Academies Characteristics and Alignment of Science Track Descriptions at Science Fiction Conventions (NRC, 2010)

National Academies Characteristics	Science Tracks at Science Fiction Conventions
"(1) designing diverse opportunities for the learner both emotionally and intellectually	There are multiple offerings within the science tracks that resonant with participants both emotionally and intellectually
(2) supporting an environment for learner-selected interactions	Participants self-select which talks they wish to go and there is no requirement of attendance
(3) facilitating events that build on prior knowledge and interests	Participants often choose talks based on cross-over interest in fandom or in science and evaluations seek to learn about future learning interest
(4) providing choice in the level and extent in which the learner participates	Participants may engage to the level they feel comfortable, they may sit and listen, or actively participate
(5) highlighting "multifaceted and dynamic portrayals of science" (NRC, 2010, p. 5)	The speakers and topics are vetted by a track committee who works to ensure participants will have a variety of topics and speakers to choose from

Just as professionals attend conferences to enhance their learning, science fiction enthusiasts attend conventions where they can interact with others in the science fiction community and share in deeper experiences of their science-related interests. Included at many of these conventions are specific learning tracks where participants can attend lectures delivered by "experts" in their field (Bondi, 2011; Slater & Slater, 2019). Tracks in this context refers to programming strands that are related by a common theme. The organization of sessions by theme allows for attendees to understand the nature of sessions that can be expected in specific context. Conventions with large numbers of offerings can be organized and identified based on the specific interests of each attendee. The experts that participate as speakers or panelists are professionals who share a common cultural interest with the participants, such as science experts who are currently in a STEM career.

One of the major differences between attending a lecture at a professional conference versus a science fiction convention is how science is communicated to the public; as the space at a convention is much more relaxed, easy to understand, and focused on a lay person understanding of the topic. A recent study by the American Academy of Arts and Sciences (2019) found that while people encounter science at entertainment venues such as science fiction conventions, there is still research to be done on the impacts of this type of science communication on motivation and interest in science. In addition, they recommend that these types of venues can play a vital role in developing "lives empowered by STEM literacy, knowledge, and identity" (p. 29). Science tracks at science fiction conventions have the potential to create spaces for community dialogue and collaboration among attendees. In addition, conventions providing opportunities for attendees to explore the connection between science and science fiction may have a positive influence on motivation and interest in science.

The interplay between science fiction, informal learning spaces, and interest in science is an untapped resource, as science fiction conventions offer an exceptionally unique opportunity to promote and engage the public in the culture of science. However, there is a dearth of literature focused on the benefits of the public attending science fiction conventions. Science fiction conventions create spaces for community dialogue and collaboration among science experts and attendees, in addition to constructing opportunities for attendees to explore the connection between science and science fiction (Slater & Slater, 2019). By making science (i.e., language, customs, and skills) accessible to the public, these informal learning environments have the potential to facilitate motivation and interest in science while making border crossings into the world of science more comfortable. Furthermore, as science fiction conventions cater to a diverse population of science fiction enthusiasts, documenting attendees' interest in science is important for the continuous improvement of science programing in an informal science learning space.

Theoretical Framework

For this study, two lenses are used to explore interest in science and future motives of science fiction convention attendees. First, general science interest will provide a framework in documenting science fiction convention attendees' interest in science. Secondly, for attendees who participate in science track sessions at science fiction conventions, the CML will provide a foundation in which to investigate how these specific attendees will utilize the science information shared at an event. These two lenses (interest and CLM) will provide insight into the public mindset regarding science at a science fiction convention.

Science Interest

As a variable, interest can document an individuals' degree of curiosity, activity level, relevance and meaningfulness, and significance related to an activity. Deci (1992) describes interest as "…the interaction between a person and an activity, operating within a social context" and suggests that interest is connected to motivation by three domains: the person, (including experiential components and dispositional components), the activity, and the social context (p. 49). The person component of interest states that interest occurs when an individual "…encounters novel, challenging, or aesthetically pleasing activities…" that allows for satisfaction (Deci, 1992, p. 49). These components describing interest are governed by the specific activity (attending science track sessions) and the associated social contexts (communication between science experts and the science fiction community) to foster motivation (Deci, 1992). Several research articles have focused science interest as a construct of study within informal science and STEM education. Overall, these studies have found 1) parental and/or guardian levels of education was a positive factor for children developing interest in science (Dabney et al., 2015), 2) a positive association between social competencies, belonging, and science and math interest (Hoffman et al., 2020), and 3) science interest is a significant mediator regarding science performance (Tang & Zhang, 2020). As science interest is a foundational construct, exploring this variable within novel informal science learning spaces, such as science track sessions at science fiction conventions, is important in examining attendee interaction and learning.

Science track sessions at science fiction conventions have the potential to merge these three domains as science track attendees are provided with opportunities to explore their interest in connecting science fiction with science fact. However, there is also importance in documenting the science interest of individuals who are not attending science track events but are engaging in other events at a science fiction convention. As a form of entertainment, science fiction conventions are a rich environment for the public to engage in science or science-related topics in the context of science fiction. However, what is unclear is the degree of interest in science, with a specific focus on the

person interest construct of individuals attending science fiction conventions and how the interest in science may differ between science track attendees and non-science track attendees.

Contextual Model of Learning (Future Motives)

To explore the actions and behaviors of science track attendees after attending a session, this research has been pursued through the lens of the CML. This theory can provide information on the motives and future applications of learning for science track attendees. CML is an appropriate framework that illustrates learning in informal contexts, which was originally applied to museum experiences (Falk & Dierking, 2000). CML is comprised of three constructs that align with the three domains proposed by Deci (1992): personal context (personal interest and intrinsic motivation), social context (connections and interactions with others), and the physical context (design of the environment) (Falk & Dierking, 2000).

Although the CML constructs are closely related to the self-determination constructs of motivation and interest, CML may provide context to the future application of learning from an informal learning context. In recent studies, the contextual model of learning has provided a foundational lens for informal science education learning spaces. Dunlop et al. (2018) found creating a *third-space* (*i.e.*, a learning space that co-existed in collaboration between the formal and informal education space) enabled student autonomy in learning and connected learning to personal interest and prior knowledge. Regarding adult learners, Childers et al. (2022) documented factors, such as social interactions and fulfilling personal needs, that motivated adults to attend science café events in their community by creating a conceptual framework based on self-determination theory and the contextual model of learning. Overall, there is a need to examine how the personal, social, and physical contexts are perceived by individuals within novel informal science education spaces.

For this study, the frameworks provide insights into how attendees participate in the culture of science when attending science track sessions at a science fiction convention in the qualitative analysis. Science tracks at science fiction conventions are situated in an environment that promotes science through the interplay of interest and motivation, via science track attendees perceived personal, social, and physical contexts. The researchers used the frameworks to provide the foundation to analyze what attendees do with the information gained after attending a science track offering.

Methods

This exploratory study documented science fiction convention attendees' interest in science and how science track attendees engage with the information they gained after attending science track sessions at a science fiction convention through an online survey instrument. The survey protocol was designed to elicit information from attendees by asking questions including demographics, interest in science, sharing the degree to which science is meaningful or relevant to the attendees' daily lives, and perceived benefits of learning science at a science track session. University institutional review board (IRB) approval was granted to obtain research data.

A survey booth was available in one of the main convention sites, accessible to all science fiction convention attendees, and was staffed by the researchers during the operational hours of the overall science fiction convention track sessions. Although the survey booth was available to all attendees, only adults (individuals 18 years of age or older) were invited to complete the survey. Both electronic tablets, connected to an Internet source, and business cards with a QR code/URL for survey access on personal devices, were provided for participants to access the survey. Survey data were housed in an online repository (Qualtrics) and downloaded onto a password protected computer and converted into SPSS and Microsoft Excel data files for analysis.

Study Context

The study site for this exploratory research was an annual science fiction and fantasy convention (Dragon Con) located in the Southeastern United States that features comics, films, television, costuming, art, music, and gaming programming related to science fiction genres. Attendance for the most recent convention in 2019 was approximately 85,000 individuals (Mandel, 2019). Attendees at this convention can choose to engage in 37 different tracks, including the Science, Skeptics and Space tracks which engage participants in informal science learning, with an emphasis on the connections between science fact and science fiction (Dragon Con, 2021). On average, there are 80-100 hours of programming available for informal science learning that encompasses these specific tracks over a five-day period, including more than 75 guest speakers and panelists, as well as sessions in other tracks that bring together the world of science and fiction (Dragon Con, 2021). The cost of attending all sessions is included in the annual conference rate (as of 2021, the annual conference rate is $115 for the 5-day convention), with no additional charges for attending specific science track sessions. At Dragon Con, there is no advance selection requirements for attendance; participants show up at the scheduled time for each session. It should be noted that these sessions, which have a capacity of 100-200 attendees, are quickly filled to capacity, and interested attendees are turned away.

The world of science fiction and fantasy allow for every possible science concept to be explored and one could expect to find a range of topics covered, including astronomy (space), biology (genetics), and physics (superheroes). Some of these activities may including multiple hour-long sessions consisting of either individuals or panels of speakers who are science experts that can connect their area of expertise within the context of specific science fiction themes. Sessions may include the accuracy of science presented in specific visual (i.e., television or movies) or print (novels, comic books, etc.) media; or alternatively connect real-world science issues to a broader science fiction genre (i.e., artificial intelligence in science fiction). For example, a session focused on genetic inheritance and inbreeding in the fictional world of Game of Thrones discussed how science may explain many of the characters' struggles (Mock, 2019).

In addition to the science track, this convention also hosts a space track, where astronomers, astrophysicists and rocket scientists provide updates on current missions and discuss other space science related themes (i.e., medical issues with space travel). Examples of sessions provided in the space track might include representatives from the private space sector who share information about private sector initiatives, as well as amateur astronomers who provide opportunities for participating in solar and nighttime telescope (on-site and remote) observations. While these sessions represent the opportunities at this convention, it should be noted that not all science fiction conventions will have the same types of informal science learning prospects.

Participants

Individuals attending the science fiction convention answered a series of questions about demographics, track attendance behavior, and science interests with additional open-ended response items. Study participants (n = 241) were adults (18 years of age or older) who attended the science fiction convention hosted in the Southeastern United States. The survey respondents included 172 science track attendees and 69 non-science track attendees (science track attendees: 74 males, 92 females, and 6 preferred to not self-identify; non-science track attendees: 32 males, 36 females, and 1 preferred to not self-identify). The majority of science track and non-science track attendees identified as white (73% and 67%, respectively) and held college degrees (science track attendees: 72% have a bachelor's degree or higher; non-science track attendees: 67% have a bachelor's degree or higher). Most of the science track attendees (68%) and of non-science track attendees (81%) were under 45 years of age. Approximately a quarter of science track attendees (27%) and a fifth of the non-science

track attendees (18%) reported their career was related to education. Chi-square tests were calculated to determine if the two groups' demographics (nominal/categorical data) were similar for comparative tests. As noted in Table 2, there was a difference in the representation of individuals with STEM careers between science track and non-science track attendee groups.

Table 2

Science Track and Non-Science Track Attendees' Demographics

Factor	Description	Science Track Attendee** (n = 172)	Non-Science Track Attendee (n = 69)	Chi-Square X^2 (p-value)
Gender	Male	45% (74)	47% (32)	0.119 (.729)
	Female	55% (92)	53% (36)	
Race	Caucasian	73% (126)	67% (46)	2.110 (.145)
Education	4-Year Degree or Higher	72% (123)	67% (46)	1.332 (.248)
Age	Younger than 45	68% (117)	81% (56)	2.861 (.091)
STEM Career	Yes	63% (108)	44% (30)	6.953 (.008*)
	No	37% (64)	56% (38)	

Note. * p-value is less than 0.05. **Some science track attendees chose not provide gender, race, education, or age demographic data.

The description of "STEM career" for this research was based on the U.S. Bureau of Labor Statistics' (2021) definition as occupations requiring "scientific or technical knowledge at the postsecondary level" including jobs related to "computer and mathematical, architecture and engineering, and life and physical science occupations" (para. 7). Furthermore, a vast majority (82%) of non-science track attendees stated that they would be interested in attending science track events at science fiction conventions if the science track events were cross listed with other events hosted at the convention. Additionally, 86% of science track attendees and 76% of non-science track attendees shared that science fiction conventions would be an appropriate place to learn science.

Survey Protocol

The survey solicited information about science track and non-science track attendees' demographics, track attendance behaviors, and interest in science using Likert-scaled items and open-ended questions designed to document what attendees will do with the information gained at a science track session. Likert-scaled survey items were adapted based on a review of literature (identifying common themes) and from two published instruments: the Relevance of Science Education (ROSE) survey (Sjøberg & Schreiner, 2010) and the Student Attitudes Toward STEM (S-STEM) survey (Friday Institute for Educational Innovation, 2012), which was originally designed to capture student and teacher interest in science, STEM, and careers related to STEM. These survey items were modified to capture a broad, public audience's interest in science and aligned to the interest construct of person. Participant responses to the 10 Likert items were on a scale of one to five (strongly disagree to strongly agree). Cronbach's Alpha was calculated with an acceptable reliability value of 0.91 (Cronbach, 1951). An open-response question specifically posed to document what science track attendees plan to do with the information gained at a science track event was present at the end of the survey if respondents indicated they attended science track sessions.

Analyses

Quantitative Analysis: In consideration for comparing groups, survey responses were analyzed and reviewed within "STEM career" groups to examine differences between science track and non-science track attendees as there was a higher representation of individuals with STEM careers in the science track attendee group than in the non-science track group. A Mann-Whitney U test was conducted to analyze comparisons between groups. This test is a nonparametric statistical test that compares two unrelated samples with a Bonferroni correction to protect against Type 1 error ($\alpha = 0.005$; two-tailed). This test is appropriate for comparison of data that is measured at the ordinal variable level that does not pass the assumptions for a parametric test. Furthermore, mean, median, standard deviation, mean rank, Mann-Whitney U test statistic, p value, and effect size (Field, 2013) for each Likert scaled-item were calculated and compared for science track and non-science track attendees.

Qualitative Analysis: The open-ended question designed to document what science track attendees plan to do with the information gained was analyzed by employing qualitative textual analysis (Creswell & Poth, 2018; Hsieh & Shannon, 2005). Approximately ninety-one percent (125 of 138) of the participants responded to the open-ended question, with answers ranging from one to 95 words. Six of the responses (e.g., "undetermined" and "probably not") could not be coded as they were too brief to provide adequate context. The average length of participant responses was 26 words and were analyzed using the components of the CML. After a review of the literature, a CML-based codebook was created. Codes corresponded to the primary constructs of CML (personal context, social context and physical context), along with their established sub-components. Statements with an emphasis on a personal interest in science, whether that interest was connected to a career or not, were coded as Personal context. Depending on the reference frame provided by the respondent, these were most often connected to the subcategories of "prior knowledge, interest and beliefs," "choice and control," or "motivations and expectations." Sociocultural codes were applied to statements in which the respondent discussed sharing information "within their social group" or "with others," including family, friends, or colleagues.

Physical context, according to Falk & Dierking (2000) includes the use of advance organizers for orientation, design of the setting, and extends to reinforcing events that go beyond the initial experience that reinforces learning. While this code was not as frequently used as the personal and social ones for exploring participant responses, it was most often applied to participant responses connected to how they would use the information they learned in specific settings as reinforcing events. For example, a specific application (rather than general) in the respondent's career such as "I repair welders and use the information to access the cutting-edge welding techniques and helps keep me employed." Other factors within the Physical context (i.e., advance organizers or design) as identified within CML were not relevant to this setting. It should be noted that some statements were coded in more than one category, depending on the complexity of their responses. For example, one participant responded to the question by stating, "I love science and like learning about different fields. And I tell stories to kids; this gives me ideas." This statement was coded as applying to both Personal (prior interests) and Sociocultural (sharing with others) factors. A total of 48% of participant responses were coded in more than one category. Three science education researchers were trained on the use of the codebook and jointly coded the data. Differences in coding were identified and resolved via discussion, and the codebook was refined and amended as the coding process unfolded. The remaining responses were divided equally among the three coders and were closed-coded for CML constructs using the refined codebook. After one round of coding (78% inter-rater agreement), the coders collaborated to resolve any conflicts in categorization resulting in a final inter-rater agreement of 97%. For each construct, frequency counts and percentages were calculated based on the science track attendee responses.

Results

Research Question 1- Are there differences between science track and non-science track attendees' (within STEM career groups) interest in science?:

In comparing science track attendees (n = 108) and non-science track attendees (n = 30) in which both groups stated they work in a STEM career, there were no differences in reported interest in science between science track and non-science track attendees. See Table 3 for this information.

Table 3

Individuals With STEM Careers – Comparison of Science Interest Between Science Track and Non-Science Track Attendees

Item (*alignment to interest construct*)	Group	Mean, Median (SD)	Mean Rank	*U*	*p* (effect size)
I find science interesting.	Science Track Attendees	4.89, 5.00 (.318)	70.36	1393.00	0.085 (0.14)
	Non-Science Track Attendees	4.70, 5.00 (.651)	61.93		
I enjoy learning about science.	Science Track Attendees	4.85, 5.00 (.357)	70.85	1474.00	0.243 (0.09)
	Non-Science Track Attendees	4.79, 5.00 (.651)	64.63		
Science has practical value for me.	Science Track Attendees	4.81, 5.00 (.582)	72.00	1350.50	0.032 (0.18)
	Non-Science Track Attendees	4.63, 5.00 (.669)	60.52		
Science is relevant to my life.	Science Track Attendees	4.82, 5.00 (.494)	69.86	1446.00	0.237 (0.10)
	Non-Science Track Attendees	4.70, 5.00 (.651)	63.70		
Science relates to my personal goals.	Science Track Attendees	4.72, 5.00 (.579)	69.84	1515.50	0.523 (0.05)
	Non-Science Track Attendees	4.63, 5.00 (.669)	66.02		
Science challenges me.	Science Track Attendees	4.79, 5.00 (.496)	71.72	1314.00	0.035 (0.17)
	Non-Science Track Attendees	4.60, 5.00 (.563)	59.30		
Understanding science gives me a sense of accomplishment.	Science Track Attendees	4.78, 5.00 (.460)	71.55	1291.00	0.051 (0.16)
	Non-Science Track Attendees	4.59, 5.00 (.568)	59.52		
I think about how I will use the science I learn.	Science Track Attendees	4.64, 5.00 (.676)	73.17	1224.00	0.012 (0.21)
	Non-Science Track Attendees	4.30, 4.50 (.794)	56.30		
I think about how the science I learn will be helpful to me.	Science Track Attendees	4.71, 5.00 (.581)	72.11	1338.00	0.058 (0.16)
	Non-Science Track Attendees	4.50, 5.00 (.682)	60.10		
I trust science.	Science Track Attendees	4.69, 5.00 (.587)	70.14	1550.50	0.634 (0.04)
	Non-Science Track Attendees	4.53, 5.00 (.937)	67.18		

In comparing science track attendees (n = 64) and non-science track attendees (n = 39) who stated they did not have a career related to STEM, science track attendees reported significantly higher scores relating to science interest (Question 1), personal relevance of science (Question 4), and sense of accomplishment (Question 7) with small effect sizes (Rosenthal, 1996). See Table 4 for this information.

Table 4

Individuals with Non-STEM Careers – Comparison of Science Interest Between Science Track and Non-Science Track Attendees

Item	Group	Mean, Median (SD)	Mean Rank	*U*	*p** (effect size)
I find science interesting.	Science Track Attendees	4.84, 5.00 (.407)	56.92	933.00	0.004* (0.29)
	Non-Science Track Attendees	4.51, 5.00 (.683)	43.92		
I enjoy learning about science.	Science Track Attendees	4.81, 5.00 (.432)	56.87	936.50	0.006 (0.27)
	Non-Science Track Attendees	4.49, 5.00 (.683)	44.01		
Science has practical value for me.	Science Track Attendees	4.64, 5.00 (.627)	55.88	1000.00	0.046 (0.19)
	Non-Science Track Attendees	4.38, 5.00 (.747)	45.64		
Science is relevant to my life.	Science Track Attendees	4.66, 5.00 (.511)	58.23	849.00	0.002* (0.30)
	Non-Science Track Attendees	4.21, 4.00 (.767)	41.77		
Science relates to my personal goals.	Science Track Attendees	4.20, 4.00 (.800)	56.44	964.00	0.041 (0.20)
	Non-Science Track Attendees	3.79, 4.00 (.978)	44.72		
Science challenges me.	Science Track Attendees	4.60, 5.00 (.661)	55.92	950.00	0.027 (0.21)
	Non-Science Track Attendees	4.31, 4.00 (.766)	44.36		
Understanding science gives me a sense of accomplishment.	Science Track Attendees	4.72, 5.00 (.487)	57.83	875.00	0.003* (0.29)
	Non-Science Track Attendees	4.31, 4.00 (.766)	42.44		
I think about how I will use the science I learn.	Science Track Attendees	4.36, 4.00 (.651)	57.36	905.00	0.012 (0.25)
	Non-Science Track Attendees	3.85, 4.00 (1.01)	43.21		
I think about how the science I learn will be helpful to me.	Science Track Attendees	4.47, 5.00 (.616)	56.69	948.00	0.024 (0.22)
	Non-Science Track Attendees	4.15, 4.00 (.709)	44.31		
I trust science.	Science Track Attendees	4.61, 5.00 (.581)	54.10	1049.50	0.180 (0.13)
	Non-Science Track Attendees	4.39, 5.00 (.755)	47.12		

Note. * denotes a *p*-value less than 0.005.

Research Question 2- How do science track attendees utilize the information provided at a science track session?

Science track attendees were asked to respond to an open-ended question to document what they do with the information learned or gained at a science track session. See Table 5 for information on primary codes, sub codes, and descriptions of the codes as well as example participant responses for each code.

Table 5

What Do Attendees Plan to Do with the Information After a Science Track Session?

Primary Code	Sub Code	Description of Code	Example Participant Responses	Science Track Attendees (%, *n*)
Personal	Factors that learners bring with them to the learning environment			66% *n* = 83
	Prior Interests and Beliefs	Desire to learn more comes from curiosity and to build on beliefs	"Recently I have become very interested in climate change because I think it is the most important challenge facing this world."	52%, *n* = 66
	Prior Knowledge	Knowledge that the individual brings to the learning experience	"I am a scientist. I like hearing about topics unrelated to my discipline at Con."	15%, *n* = 19
	Prior Experiences	Prior activities and background that influence the individuals desire to learn more	"I'm a physician. Sometimes I use it in my practice. Sometimes I use it in general conversation, or as an analogy in my practice or socially."	17%, *n* = 21
	Motivations and Expectations	Intrinsic motivations and desire to meet expectations contribute to learning experience	"I would like to further my career."	53%, n = 67
	Choice and Control	Learning facilitates choice and control	"Shape the world around me in a better light."	35%, *n* = 44
Social	Factors that influence learning come from the shared setting or facilitates social experiences by sharing new knowledge			42%, *n* = 53
	Within Group Interactions	Learning within a group setting provides benefits	"It helps me hold conversations with friends – passing on knowledge."	25%, *n* = 32
	With Others	Social learning that extends beyond one's social group	"I am a writer and use the information to ensure the science and facts in my stories are as correct and accurate as possible."	32%, *n* = 40
Physical	Factors that relate to what the learning experience brings to the individual in and beyond the physical learning environment			34%, *n*= 43
	Advance Information	Advance information helps provide motivation for learning	"Who knows, might come in handy specifically at some point, but even if it doesn't, I just enjoy knowing and understanding all kinds of stuff."	9%, *n* = 11
	Orientation to Space	Factors that relate to the learner's ability to navigate the learning environment	N/A	No coded response.
	Architecture Design Factors	Physical layout of information influences learning	"I love to be able to watch panels via streaming after the con, as sometimes I have to choose which of several things to attend."	1%, *n* = 1
	Design and Exposure to Programs	Factors that relate to the design of the learning experience	"Learning about science and new fields allows me to learn in a n informal and fun setting which later encourages me to do independent research and read research journals on my own."	1%, *n* = 1
	Reinforcing Events	Benefits of applying knowledge gained beyond the learning environment	"I use the information as seeds and water for ideas and playtime projects."	28%, *n* = 35

Note. Some science track attendees share more than one reason related to the codes described above.

Participants answering the open-ended prompt were allowed to provide a response that might align to more than one thematic code. Most attendees (66%) shared personal factors, such as prior experiences and beliefs, as how they plan to use the information to improve their daily lives. Statements that were coded for personal factors most often indicated some degree of personal interest which was often, but not always, connected to their career. For those whose interest was outside of their career, they often cited they would use the information they learned as, "fodder for self-improvement," for "personal enrichment," or for "developing critical thinking skills." For those whose interest was connected to their careers, they often started their response with, "I am a…." or "I work in…." then proceeded to explain their interest and how what they learned would apply to their career. For example, one respondent stated, "I'm an astronomy enthusiast, journalist, and photographer. I will use information gained from the Science track as a research resource." Other respondents showed a personal interest based on a passion for learning and felt that the information they learned would enhance their life. For example, one person who stated, "Science is the basis of EVERYTHING. Anything I can learn everyday adds purpose and understanding to our lives and improves my qualify of life in many ways. Knowledge is power. I want to learn all I can of this world while I'm still here!"

Approximately 42% of attendees indicated that they share the information obtained from a science track session with others (e.g., peers, colleagues, students, family, and friends). The responses coded within a sociocultural context related to respondents sharing information they learned in the science track within their social group or with others. For those who discussed how the information connected to their job, a sociocultural context was only also applied when their responses indicated they would engage in conversations with their peers based on what they learned. One example of this is the statement, "I work with children and teens, so sometimes I share what I've learned with them." Many of the respondents indicated the knowledge they gained in these sessions would be used informally, or in "conversation topics with friends." One respondent provided that they would share the information more creatively, "I tell stories to kids, this gives me ideas."

Over a third (34%) of attendees cited physical factors for impacting how they might apply the information in their daily lives. These responses aligned with CML as a reinforcing event, and for coding purposes, was always associated with a specific action. These respondents often indicated that the information they learned would be used in a work context to achieve a specific purpose, such as to, "create new approaches and concepts" (in computer applications) or to, "advocate for more funding for graphene research." Often, non-work-related applications were mentioned, such as one respondent who indicated they would use the information gained in their daily life by claiming "I learned some facts about water usage that will make me think about my water consumption in my daily life." It should be noted that this specific response was coded in multiple contexts (personal and physical). The application of the physical code (reinforcing event) was connected to the specific way in which the information would be applied in a specific context or setting beyond the session.

Limitations

Interpretation of the results and subsequent implications of this study are limited to the design of the survey, demographics of participants, and access to participants at a science fiction convention event. Although the survey protocol was modified from existing surveys and informed by literature concerning adults in informal learning environments, the results are not generalizable and are limited to this specific study's site, context, and population. Other science fiction conventions may have different structures when it comes to hosting science track sessions as well as target specific groups of people to attend. Another potential limitation is the number of people who answered the survey. Due to the small, focused area where the researchers were located, the traffic pattern compared to number of attendees was limited. Additionally, there may be limitations related to financial issues that

may affect who can participate due to the costs associated in attending the convention, such as buying a convention membership ticket and traveling to the convention. Future research should focus on survey protocol development to document specific science education factors of adults in these informal learning contexts. Finally, research designs in investigating science fiction conventions as spaces for learning science could provide awareness of how to engage the public in science discourse to support a science literate populace.

Discussion

Science fiction conventions provide a unique opportunity for public access to science experts through science track events. It is important to recognize the potential effect of science fiction convention events on the understanding of science and the potential for impacting scientific literacy with the public. Through the opportunities these conventions offer for the public to engage in the language and conventions of science, those that attend these events may find it easier to participate in the culture of science. Science fiction conventions, as collaborative learning spaces, can connect science enthusiasts from all walks of life, including teachers, experts, students, and the public to scientific endeavors. These conventions could potentially support a rich learning experience for the public to engage in open-dialogue discussions with scientific experts, as well as an opportunity for science educators to engage with the community and expand their knowledge of scientific concepts and applications.

Diversity at Science Fiction Conventions

Science fiction convention spaces could support the learning of science with diverse communities. As noted in the demographic information, almost a third of attendees who participated in the study did not identify as white, the majority of attendees were young (under 45 years of age), and there was an almost equal representation of male and female respondents to the survey. These demographics may suggest that science fiction conventions might be an untapped science learning environment, connecting to a younger, more diverse community. Representation of diverse voices in science, STEM careers, or STEM learning environments is often limited due to perceived barriers (Hite et al., 2019; Sadler et al., 2012; Saw et al., 2018; Swafford & Anderson, 2020). As such, science fiction conventions could provide a unique opportunity for the public to interact with scientists, which may help deconstruct general misconceptions of science and scientists, and provide educational programming. Because Hasse (2015) noted that there may be cultural and gender biases and barriers that may limit participation of some individuals in these spaces, future exploration on how these groups participate in these spaces is warranted as women, diverse racial/ethnic groups, and individuals in varying socio-economic strata are attending these sessions. Highlighting the current landscape of global connection and the understanding of the impact people have on each other, the need for a scientifically literate populace, and the need for individuals to pursue STEM careers, it is imperative to support informal learning experiences that transcend the traditional formal and informal learning environments wherever they are found for diverse audiences and to allow for broader participation in the culture of science.

Science Interest and STEM Careers

There may be underlying influences or factors of career choices that may be related to attendees' science interest. There were no identified differences of interest in science between science track and non-science track attendees when the attendees reported having a STEM career. However, for those attendees who stated that they did not have a career related to STEM, there were reported

differences in science interest items between the science track and non-science track attendees. Jones et al. (2019) found that adult STEM hobbyists, who had a STEM career, reported that their choice to have a career in STEM was influenced by the involvement of their informal learning experiences within the STEM hobby. In examining university students' STEM interest, Dabney et al. (2012) shared that involvement in out-of-school time science events, middle school interest in science, and gender were significant factors in STEM career interest. For science fiction convention attendees, involvement in a STEM career may be influenced by interest in science. However other factors, as noted in the aforementioned studies, may also provide information regarding the difference in science interest items among attendees who did not have a STEM career. Overall, 82% of non-science track attendees stated that they would be interested in attending science track events at science fiction conventions. Further analysis of this finding was explored to determine the interest in attending science track sessions among the non-science track attendees based on the attendee's career. Seventy-nine percent (n = 27) of non-science track attendees who had STEM careers, and 86% (n = 25) of non-science track attendees who did not have STEM careers, had interest in attending science-track sessions if cross listed in the convention programming. This may suggest that although there may be differences in science interest among non-science track attendees in relation to attendee STEM career choice, in general, non-science track attendees would participate in science track sessions if they are aware of the opportunity. Furthermore, participation in science fiction convention events may influence individuals' interest in science and career choice. This may provide the foundation to support future research into accessibility and efficacy of science programming, fostering science interest, and examining factors related to STEM career choice and the participation in science fiction convention activities for the public.

Border Crossings into the Culture of Science

While the CML is a framework designed specifically for exploring learning in informal, museum contexts, it is appropriate for this setting. Rather than consisting of exhibits, science fiction conventions provide "tracks" in which attendees choose to participate. By exploring the motives of science track attendees in the science fiction setting through the lens of the CML framework, insights are provided about how adult learners utilize what they learn in informal settings. According to Falk and Dierking (2000), CML recognizes that learning is complex and situated. Context is important for "learning that has also been emphasized by others" (Falk et al., 2007, p. 745). Track sessions within this setting provide an unusual context for informal learning in which attendees interact with experts and others.

Within this setting, Personal factors are most often cited by attendees (66%) for how they use what they learn in this setting most often connected to "motivation and expectations," and "prior interests and beliefs." While many attendees selected specific sessions because of their education, prior experiences, or jobs, many attended sessions because of the opportunity to learn for the personalized purpose of "personal enrichment." New knowledge is an end in itself, providing "new things to mull about" or "fodder for self-improvement." The desire to learn new things for the sake of learning seems to be enough of a purpose for a great many attendees. In the words of one participant,

> I like learning about the universe we live in and the possibilities for our future. As an informal learning environment, these sessions provide opportunities for individuals to engage in the culture of science for the joy of learning, without a specific or predetermined purpose.

Sociocultural factors related to the motives of attendees suggests that a large percentage (42%) of these attendees felt that the new knowledge they gained in these sessions was worthy of sharing with others, both within and outside their social group. While learning in this environment is socio-

culturally situated, the intent of these attendees was to extend that context in sharing what they learn, "in conversations with friends," "family," and "with my students and colleagues." It should be noted that the new knowledge these track attendees gained improves the quality of their interactions with others by allowing them to "be more informed," and to "speak more knowledgeably." In the words of one participant, "I don't want to be someone who speaks out of their rear end." Being able to engage in conversations with others about scientific "norms, practices, language and tools" (NRC, 2010, p. 20) is an important way in which individuals can participate in the culture of science.

Because our question related to how attendees planned to utilize what they learned, the Physical factors cited by participants tended to connect to reinforcing events and experiences beyond the science fiction convention. Most often these responses were connected to specific work-related purposes, such as "to improve treatment/outcomes" or to "create new approaches and concepts." Less often, personal uses for new knowledge to reinforce events and experiences are cited such as, "to inform my politics and influence which issues I contact my elected representatives about," or for "creating costumes." Therefore, the knowledge gained by attendees serves specific purposes in how it is applied in a Physical context, beyond the immediate setting, building on the importance of learning that is connected to Personal and Sociocultural factors.

Conclusion

Overall, science fiction convention attendees may be interested in exploring more informal science learning opportunities in these spaces, supporting the position that science fiction conventions have a rich potential as learning environments for informal science learning. The results of this study indicate that there is a diverse population of attendees who are interested in the connection between science and science fiction, as well as share specific motives and intentions regarding their learning at science track sessions. Science interest and motives provide a unique perspective into how science fiction convention attendees learn about science, who they share their learning of science at these events with others, and how they integrate this learning into their own personal or professional spaces. Science track supervisors and convention planners could use the information garnered here and in future research to better market and advertise non-fiction offerings at conventions. By cross listing non-fiction panels with panels solely related to the fictional aspects of science fiction, these venues could potentially reach more people who are unaware of science programming offerings at conventions and who might benefit from such offerings. In addition, the diversity of attendees in this study (e.g., majority of the attendees were under 45 years of age; a third of attendees identified ethnicity/race as non-white; approximate equal representation of males and female attendees) could provide an opportunity to engage a broader cross section of the public in science. This may be achieved by engaging them in informal learning environments, where science fiction interest and science merge. In future studies regarding science fiction conventions as places to learn science, the term *diversity* should be more inclusive including women/non-binary (gender minorities), non-white (racial/ethnic) minorities, and individuals with disabilities.

Furthermore, approximately 20% of the participants in this study shared their occupation was related to education, and many participants conveyed the notion that they would integrate their learning from the science tracks into their professional lives, including creating lessons. Although these findings are encouraging and show that educators are seeking out ways to further their knowledge through informal learning and non-traditional professional development activities, more research is needed. Future research in this area may determine how educators are utilizing science fiction and science fact gained from science fiction conventions in their classrooms, whether this data is similar across the United States, and how to leverage informal learning into professional development. This information can be of particular interest to those who plan and implement professional development and researchers studying both formal and informal education contexts through the lens of science

fiction. Science teachers could also benefit from this information as they consider ways to make connections with scientists in the field who have experience in communicating with the public. Future research may need to focus on attendee life-span choices, interest, cultural and social factors, and experience as to investigate how interest in science may influence the choice or engagement in science in informal learning contexts. Lastly, there is a need to examine additional factors, such as the flow of information from scientist to the community, which may enhance the understanding of how science information is viewed, perceived, and shared in science fiction convention spaces. Based on the ever-changing landscape of educational policy and practice, the interaction between the public, science experts, and formal and informal learning environments and experiences may be crucial in supporting science literacy.

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