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Pedro Donizete Colombo Junior 
Federal University of Triângulo Mineiro (UFTM), Brazil

Martha Marandino 
University of São Paulo, Brazil

Graziele Scalfi 
National Institute of Public Communication of Science and Technology (INCT-CPCT), Brazil

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Biodiversity and Science, Technology, Society and Environment (STSE): Visitor Perceptions at a Science and Natural History Museum

Pedro Donizete Colombo Junior, Martha Marandino, Grazielle Scalfi

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Abstract

This qualitative study investigated perceptions of STSE topics manifested by adults visiting four biodiversity exhibits at the Royal Ontario Museum (ROM) in Toronto, Canada. Seven visitors were observed by researchers during their visits and completed post-visit interviews. The theoretical perspective on STSE relationships expounded by Pedretti and Nazir (2011) and Steele (2014) was adopted for the analysis portion of this investigation. Results indicate that the exhibits were able to communicate their central messages on the relationship between human beings and the natural world and the relationship between science and society, as well as reveal some of the effects that these messages had on the public. However, results also support the assertion that some of the intended STSE concepts were not perceived by the participants. Moreover, we identified limitations regarding adult visitors' abilities to perceive science and technology as human activities embedded in a social, historical and moral context.

Introduction

Museums of natural history, science, and related fields are scientific and cultural institutions with enormous potential for the promotion of public science and technology communication. Through their exhibits, educational activities, and technological resources, these institutions become attractive science entertainment and learning destinations for all types of people, regardless of age or educational background (Simon, 2010). Moreover, these institutions can contribute to the expansion of Scientific Literacy (SL) and the engagement of citizens on issues related to science and technology (Leitão, 2017; Schuindt, Silveira and Lorenzetti, 2018; Henriksen, Frøyland, 2000). Relationships between science, technology, society, and the environment (STSE) are generally presented as complex, as they involve multiple contexts, actors, and subjects. Pedretti (2003) mentions that,

[...] it would be a mistake to assume that STSE is a single, coherent, well-articulated approach to science education, nor should it be. If the spirit of STSE education is to explore the relationships among science, technology, society and environment, then we cannot hope to capture this complexity in a neat unencumbered package (Pedretti 2003, 221).

Though STSE education constitutes a promising path to Scientific Literacy (SL) both in scholastic environments and in informal education settings such as science museums, science is generally presented by science museum exhibitions as isolated from its original context. According to Pedretti et al. (2001, 403) "visitors at a science

center experience a similar representation of science (school) that is monolithic, objective, and apolitical, though often in an interactive, hands-on environment”. To paraphrase, the author asserts that scientific knowledge is routinely presented in a manner that, though interactive and engaging, excludes discussions of the process through which this knowledge was constructed and the socio-cultural context in which its construction was embedded. Pedretti goes on to express discomfort with this evaluation, as “science and technology cannot be divorced from their social purposes and responsibilities, doing so errs in presenting science as a value-free, abstract, and objective pursuit” (Pedretti 2003, 31).

That being said, expositions focused on STSE relationships and sensitive, controversial themes have become more and more common. Examples of such themes that have been presented in science and natural history museums include climate change, loss of biodiversity, deforestation, exploration of the impacts of and challenges surrounding environmental issues, and the necessity of activism on the part of individuals and society at large. In a literature review written by Marandino et al. (2016, 15), STSE education strategies such as the presentation and use of socio-scientific subjects, simulations, decision making, and debates were successfully identified at critical science exhibitions – exhibitions that address scientific controversies – and exhibitions that use dialogue as a communication model.

Science museums play an important role in disseminating information, supporting science learning, and promoting critical analysis and reflection, having demonstrated their ability to problematize and create change in the way in which visitors think about scientific themes (Gutwill, 2018; Falk, Dierking, 2012; Packer, Ballantyne, 2005). As such, understanding the impact of visits on museum audiences is a relevant research topic. Thus, in this article, we aim to investigate the perceptions on the theme of biodiversity that adults manifested after visits to exhibits at a natural history museum. We also discuss the role that these spaces play in the public’s internalization of the idea that science and technology cannot be divorced from their social purposes and responsibilities.

Purpose and Objective

This study aims to investigate the perceptions manifested by adults regarding STSE relationships on visits to four exhibitions dedicated to biodiversity at the Royal Ontario Museum (ROM), Toronto, Canada. Our focus was on identifying these perceptions and analyzing how they were articulated in relation to STSE themes. To this end, two questions guided our investigation: What perceptions does the adult public hold regarding how biodiversity is presented at science museum exhibits? How are STSE relationships perceived by visitors during their interactions with biodiversity-themed exhibits?

Framework

Biodiversity at Museums

The theme of biodiversity is explored at a variety of science museum types, including botanical gardens, zoos, and natural history museums. Biodiversity exhibition specimens, in general, perform the function of communicating concepts and ideas in the natural sciences, such as species’ geographic ranges, morphology,

physiology, ecology, and taxonomy, as well as changes in organisms and environments over time, among others. Aspects related to the conservation of biodiversity are also present, often alerting the public to the impacts and losses suffered by ecosystems and organisms. Knowledge of species' ranges, relationships with other organisms and the environment, and their conservation status is fundamental to understanding the relevance of biodiversity conservation initiatives (Novacek & Goldberg, 2013; Marandino & Rocha, 2011; Marandino et al., 2019).

Studies that analyze how the theme of biodiversity is presented at exhibitions indicate that expositions related to the hierarchical organization of species within ecosystems, evolutionary and biogeographical elements, and aspects of species conservation are commonplace. However, the social and human dimension of biodiversity, related to the diversity of human groups and their relationships with their environments, is not always addressed at these exhibits. When this dimension is addressed, it is often in a cursory manner (Mônaco & Marandino, 2010; Marandino & Diaz Rocha, 2017).

Discussing biodiversity conservation efforts, their causes, and their consequences while promoting reflections on humanity's relationship with their environment is an educational initiative that has become increasingly necessary as deforestation, forest fires, violence against forest people and biodiversity losses have intensified around the world. Although, on one hand, more information is available and more content is produced on this theme, on the other, active engagement and behaviors that lead to a more sustainable future have been reduced (Jordan et al., 2009). In this context, it is essential that museums promote exhibitions that address the theme of biodiversity in its scientific and technological dimensions as well as its political, aesthetic, social, and cultural dimensions.

Some studies have demonstrated, for example, that overall comprehension of biodiversity and knowledge of conservation initiatives are significantly higher in visitors to these institutions (Jensen, 2014; Moss, Jensen and Gusset, 2014, 2017). Ballard et al. (2017), for example, analyzed 44 citizen science programs at three natural history museums in terms of their contributions to conservation. The authors demonstrated that these programs not only support conservation directly through management of the local environment and extant species, but also indirectly through research, education, and public policy.

However, spurring changes in attitudes related to environmental issues and evaluating the impact of exhibits in relation to this objective remains challenging. Balmford et al. (2007), on evaluating 1,340 zoo and ecological park visitors, found little evidence to support the assertion that a single visit has the potential to create measurable change in knowledge, concern, or capacity for useful action on the part of visiting adults in regard to biodiversity. Though, the authors do not go so far as to reject the important function that these spaces have the potential to perform in educating or inspiring the public on relevant topics.

It is noteworthy that studies investigating the impact of exhibitions on visitors, especially adult visitors, are relatively few in number, necessitating further research to gather evidence on the potential impacts of museum visits on visitor perspectives regarding this theme. Such studies would also prove beneficial to museum staff in regard to exhibit planning, public communication, and their contributions to forming citizen-scientists. In light of these benefits, our study was designed with the goal of characterizing the adult public's perceptions on biodiversity during visits to exhibitions at the ROM.

Studying the Adult Public's Perceptions through the Lens of the Seven STSE Currents

In this study, the act of perception is understood to be a process that allows the individual to recognize, organize, interact with, and react to received environmental stimuli (internal and external) and interpret them in order to constitute their meaning (Marques et al., 2020). From the perspective of environmental studies, the study of perception has been recognized for its potential to investigate the interrelations of humans and the environment in terms of human expectations, values, attitudes, satisfaction and dissatisfaction, judgements, and behaviors (Santos and Oliveira, 2015). These elements are intimately related to environmental awareness, as it is presupposed that greater awareness leads to higher quality interactions between humans and their environment (Marques et al., 2020).

In order to understand adult visitors' perceptions of biodiversity and STSE relationships, we grounded our investigation in the work done by Pedretti and Nazir (2011) and Steele (2014) on STSE issues. Pedretti and Nazir (2011) delimit six STSE currents based on their theoretical review of the topic in formal educational settings in order to distill and crystallize the essential characteristics of each relationship type.

Marandino, Navas Iannini, and Pedretti (2023) used those currents to analyze the Shad Gallery (ROM), using them as categories to study the potential of the exhibition to promote the relations between STSE. The currents are: application/design, historical, logical reasoning, value-centered, sociocultural, and socio-ecojustice. In a critical analysis of Pedretti and Nazir (2011), Steele (2014) proposes the inclusion of a seventh current, labeled experiencing the natural environment, in reference to human affective, sensory, and intuitive integration with the environment. In this study we adopt the seven-current framework in order to evaluate an informal educational space and characterize audience perceptions after visiting four exhibitions. The currents are explained below:

1. Application/design: This current highlights the practical and utilitarian dimensions of scientific knowledge. It focuses on solving problems through the design of new technologies or modifications to existing ones (Pedretti and Nazir 2011). Emphasis is placed on developing skills, the relationship between science and technology, and the development of cognitive skills for the application of acquired scientific knowledge. This current proposes student involvement in situations that resemble real-world challenges, for example in problem-based learning, where students might demonstrate scientific principles and thinking, propose novel ways of completing a task, or create a technology in order to solve a given problem.

2. Historical: Focus on understanding the socio-historical aspects of scientists' work and the context in which scientific knowledge emerges defines the historical current. STSE education based on this current examines the process of scientific development from a perspective that includes analysis of the key actors involved, relevant historical facts, and socio-political milestones. According to Pedretti and Nazir (2011), this current understands science as a constructive endeavor carried out by human beings (with weaknesses, strengths, ambitions and feelings), in which collaboration with the study of the History and Philosophy of Science (HPS) "allows for the exploration of complex epistemological questions" (Pedretti and Nazir 2011, 610). Criticism of this current, the authors point out, is centered around its reinforcement of conception of science in the classroom in which scientific

progress is depicted as the result of momentous contributions made by individual heroes, disregarding the errors and failures inherent in the construction of scientific knowledge. Gil-Perez et al. (2001) argue that this elitist, individualistic view is a distorted representation of scientific practice, in which 'scientific knowledge appears as the work of isolated geniuses, ignoring the role of collective and cooperative work' (Gil-Perez et al. 2001, 133).

3. Logical reasoning: The cornerstone of this current is its assertion that scientific knowledge based on empirical evidence is the only means of effectively interpreting and enabling decision-making at a societal level. In this current, the exploration of scientific information and data takes center stage, and the understanding of socioscientific subjects 'can be effectively synthesized through consideration of the science behind the issue and positivist, logical reasoning regarding its consequences' (Pedretti and Nazir 2011, 612). In counterpoint, Gil-Perez et al. (2001, 136) have warned against 'the rejection of an empiricism that conceives knowledge as the result of inductive inference based on "pure data"', as these data are meaningless in themselves and must be interpreted in light of theory.

4. Value-centered: STSE decisions are based on moral and ethical sensibilities. Scientific knowledge is understood as inseparable from values and socio-cultural, political, and economic conditions. For Pedretti and Nazir (2011, 613) 'a number of reports reveal that values are an intrinsic part of people's consideration of SSI (socioscientific issues)'. This view of STSE relationships is accurate in noting that the nature of scientific knowledge is not free from the influence of social constructions that promote citizenship. According to Santos and Mortimer (2001, 107) 'a scientific education that intends to be neutral is ideologically biased (...) instead of preparing the citizen to participate in society, it can reinforce values contrary to the ideal of democracy and citizenship through lack of questioning'. Steele (2013, 21) argues that current value-centered strategies 'include [consideration of] case studies and socioscientific issues through an ethical lens'.

5. Sociocultural: Here science and technology are described as elements of the social and cultural contexts in which they occur, promoting the perspective that science should be accessible to all. Emphasis is placed on the idea that scientific knowledge is one of multiple approaches to apprehending and interpreting the environment in which we live. For Pedretti and Nazir (2011, 616) science 'is seen as a significant resource that all people can use and contribute to, but at the same time is not necessarily a superior form of knowledge'. Gil-Perez et al. (2001) state that a decontextualized, socially neutral image of science constitutes a distorted representation of scientific practice and its complex relationships, claiming that 'the actions of scientists have a clear influence on the physical and social environments in which they are inserted' (Gil-Perez et al. 2001, 137). It is important to consider, however, that 'although nothing guarantees that scientists will make sound decisions, their choices are not totally blind: there is always evidence for or against each alternative, and it is possible to weigh each one and form preferences based on knowledge available at the time' (Martins, 2006, xxiii).

6. Socio-ecojustice: This current discusses the need to criticize and seek solutions to social and environmental problems that originate from the effects of human actions on the environment. The development of initiatives in specific contexts (citizens' immediate, daily lives) and the application of democratic principles are its most salient characteristics. Santos and Mortimer (2001, 103) point out that '(...) science is not a politically and ethically

neutral activity (...) understanding the political and economic context in which S&T is produced is fundamental to the decision-making process'. This current promotes civic responsibility and citizenship, among other qualities, and emphasizes the transformative and emancipatory aspects of criticizing and seeking to solve problems of a social and/or environmental nature and facing social and environmental injustices (Steele 2013).

7. Experiencing the Natural Environment: Citing Lucie Sauvé's mapping of environmental education currents and the six currents proposed by Pedretti and Nazir (2011), Steele (2014) suggests the demarcation of this seventh current. The experiencing the natural environment current promotes exploration of the natural environment in an immersive manner and reflection on how human beings could or should interact with nature. Steele (2014) argues that cognitive and affective experiences had by students in natural environments are fundamental for STSE education. This new trend was developed based on research performed by Steele while investigating the practices of high school science teachers in rural communities in the northern Ontario region of Canada on the topic of resource extraction (focusing on environmental education) (Steele 2013). During these analyses, Steele inferred that there was no direct focus on environmental education in Pedretti and Nazir's (2011) STSE currents and, in 2014, supplemented their efforts by creating the experiencing the natural environment current.

Methodology

Qualitative research involves reflection on and analysis of observed events, employing methods and techniques to arrive at a detailed understanding of the object of study within its context (Oliveira, 2008). For Bogdan and Biklen (1994), the direct data source in the qualitative approach is the natural environment itself, which is situation-specific and complemented by information obtained through other data-collection methods. In this type of research, process is more important than product, as its goal is understanding the processes through which meanings are derived. For Creswell (2013), qualitative research implies a process that involves data collection, data analysis, and report writing, which are interrelated and often occur simultaneously during investigations. This qualitative study is characterized as a case study, an investigational strategy that emphasizes experiential knowledge gained during actual occurrences of the phenomena at hand (Adelman, Jenkins, and Kemmis, 1976; André, 1984), allowing researchers to better approximate the specific context under analysis. Below, we describe the study's location and the methods employed for data collection and analysis.

Study Context: Biodiversity Exhibits at the Royal Ontario Museum, Toronto

The Royal Ontario Museum was founded in 1914 and is administered by the Ontario Ministry of Culture. It has a collection of more than '[...] 13 million artworks, cultural objects, and natural history specimens featured in 40 gallery and exhibition spaces' (Royal Ontario Museum 2021a, online). Its activities include serving the public through permanent and temporary exhibitions and performing research in various disciplines, including biodiversity.

The exhibits on display at two of these galleries were selected for this study: the Patrick and Barbara Keenan Family Gallery's "Hands-on Biodiversity" exhibit and the Schad Gallery of Biodiversity's "Biodiversity: Life in

Crisis” exhibit. These exhibits are integrated with two additional expository spaces: the “Bat Cave” and “Birds” spaces, as shown in Figure 1. All spaces are located on the museum’s second floor. Through specimens, dioramas, interactive apparatuses, and immersive environments, the four spaces allow visitors to appreciate the often-complex interdependencies between living beings in an accessible way, reflecting on the museum's collections and research. The museum also makes trained mediators available to assist visitors (Royal Ontario Museum 2021b, online).

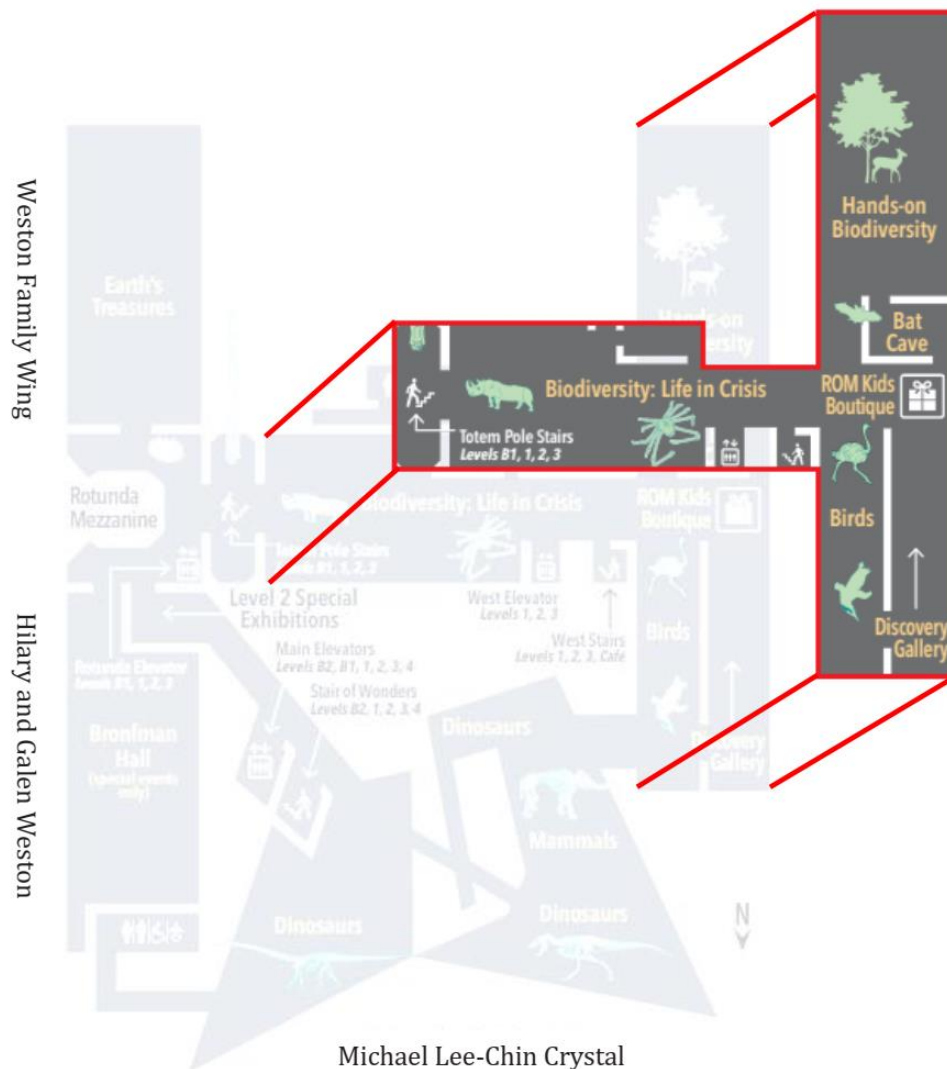


Figure 1. Second Floor of the ROM. Highlighted, the analyzed spaces: Hands-on Biodiversity, Bat Cave, Biodiversity: Life in Crisis, Birds.

Source: ROM map guide (Royal Ontario Museum 2016, 5, adapted by the authors).

Credits: Royal Ontario Museum - Michael Lee-Chin Crystal by Daniel Libeskind.

The Hands-on Biodiversity exhibit offers visitors the opportunity to observe and handle hundreds of specimens. It is an interactive gallery built from the museum's collections and research work. The Biodiversity: Life in Crisis exhibit, installed in the Schad Gallery, was supported by donations from the Schad family. The purpose of this exhibition is to explore life on planet Earth through displays of taxidermied, conserved, or modeled animals,

plants, fungi, etc., which are representative of different ecosystems. It also aims to emphasize the importance of biodiversity conservation (Royal Ontario Museum, 2015). The Bat Cave is an immersion exhibit where visitors can enter a cave showing how bats live in their natural environment. Finally, the Birds exhibit is a traditional (non-immersive) exhibit where various taxidermied avian specimens are shown.

Data Collection

The data were collected between October 2017 and January 2018. Adults were invited to participate in the study by a member of the research team who explained the purpose of the study and invited them to visit the museum on a specific day. Selection of participants was based on previously established criteria of i) accepting a free visit to the museum's selected exhibition spaces, ii) having obtained a college degree in any area, and iii) being willing to participate in an interview at the end of the visit.

Seven adult visitors agreed to participate in the study and signed the Informed Consent Form (ICF). During their visit, they were observed by a researcher and, at the conclusion of their visit, participated in a semi-structured interview. Visits were recorded using portable audio recording equipment fixed to the participants. The accompanying researcher maintained enough distance from the visitor so as not to interfere with their visit, and used film, photographs, and field notes to record their behavior.

Notes were made on general information such as visit duration, route taken by the participants through the exhibits, and actions they performed (such as observation of expository elements, reading texts, taking pictures, interactions with touchscreens, and conversations with other visitors). At the end of the visit, the semi-structured interview was recorded. These observational data and field notes comprise the data set analyzed in this study.

During data collection, we composed a descriptive text based on visitor impressions, attempting to formulate how the participants interpreted exhibit elements during their visit, as proposed by Bogdan and Biklen (1994). To that end, the final interview script contained eleven questions divided into three sections:

- i) questions related to participants' general impressions about the exhibition spaces and their perceptions of what biodiversity is and how it is represented in the exhibition,
- ii) questions exploring the participants' perceptions of how the exhibition portrays the "Life in Crisis" theme and how biodiversity loss is presented, and
- iii) questions exploring their perceptions of if and how controversial biodiversity issues are presented and whether museums exhibitions are appropriate places for the display of sensitive, conflicting, or divergent viewpoints on biodiversity.

This data set allowed us to analyze visitor perceptions of biodiversity and how STSE relationships relevant to this theme were represented in their interactions during the visit.

Participants

The group of visitors that accepted our invitation to participate in the study was composed of five women, one

man, and one person who declined to identify their gender. In regards to nationality, there were three Canadians, two Brazilians, one American, and one Argentinian. In order to maintain anonymity, participants are identified by number (e.g. Participant 1, Participant 2, etc.) (see Table 1).

Table 1. Characterization of Research Participants

Participant	Age	Gender	Degree Area	Nationality	Occupation
1	30	F	Science and Arts	US American	Graduate school research assistant
2	42	F	Journalism	Brazilian	Professor
3	42	M	Music	Argentinian	Freelancer
4	32	F	Biology	Canadian	Student
5	27	F	Psychology	Canadian	Researcher, professor
6	32	Not informed	Study of critical deficiencies	Canadian	Volunteer working with special needs students
7	54	F	Biology	Brazilian	Scientific Researcher

Font: the authors.

Data Analysis

In order to understand visitor perceptions related to STSE and biodiversity, our primary analysis consisted of reading and interpreting field notes, observational data, and interview transcripts, after which the data set as a whole was annotated, classified, and interpreted. The previously described STSE currents were used as classifiers. Creswell (2013) describes the spiral method of qualitative data analysis as one in which data is described, classified, and interpreted in a cyclical fashion in which codes or categories are formulated over the course of the cycle's iterations. In this study, we began this type of analysis using predetermined categories from a theoretical model described in the literature (Creswell 2013, 185) in order to focus on STSE relationships. As pointed out by Creswell, the use of predetermined categories can limit the interpretation of participants' views and, for this reason, he encourages researchers to be open to adding new codes or categories that emerge during analysis.

Taking this into consideration, we proposed 3 analytical categories, or themes, supported by the literature but constructed from our own interpretations of the interviews, observational data, and field notes:

- Theme 1 - Biodiversity Concepts: referring to conceptual and interpretive aspects, with an emphasis on the definitions, concepts, and contextualization of biodiversity at the exhibit. This theme is focused on the exploration of scientific information and data.
- Theme 2 – Biodiversity Values: regarding the impact of human activities that lead to biodiversity loss. Includes suggesting solutions to environmental challenges and elicitation of reflections on human values as they relate to environmental issues.
- Theme 3 – Activism and Biodiversity: exploring the political and social relationships between science and society. This theme centers around interventions intended to mitigate the impacts of human activity on biodiversity.

Results and Discussion

Theme 1 - Biodiversity Concepts

Recorded dialogue that was categorized under this theme corresponds to the perceptions that participants manifested regarding the conceptual aspects of biodiversity. Using the exhibits' expository elements and texts as support, participants discussed a range of scientific concepts and content related to biodiversity, varying in depth from simple reflections on life's diversity to more elaborate responses that included descriptions of specimens and environments.

Participant 2: 'Yes ... there is a part of the exhibition that says biodiversity (...) there are three levels of biodiversity. I passed, I read. It was funny because, my idea of biodiversity ... is about different species and ecosystems. Much more related to species, biodiversity is different ecosystems and different species in each ecosystem. But when I read it here, I learned that it is like having three levels, there is genetic biodiversity, there is diversity between species and also ecosystems. So, my idea was very vague. It was just that: the idea of diversity of life on Earth'. (Interview)

Participant 7: '(...) (I) don't know if others will classify it like that, there is all the preparation, the cataloging of vegetables that you can explore, and even the cataloging of animals. There are drawers that I call interactive that you can pull and look at, so it's not just the exhibition itself. (...) what I saw is well described, well cataloged, and well explained. I thought the tree they set was really cool, how they teach (...) the age of the tree. How you see meristems, and all that part, I found it very interesting'. (Interview)

Scientific perspectives related to the general idea of the 'diversity' of organisms and the different levels of biodiversity, especially species and ecosystems, can be found in these excerpts. The participants' working definitions of the term biodiversity varied in accordance with their scientific knowledge, viewpoints, values, and experiences with nature. Studies on public perception of biodiversity demonstrate that people do not have a uniform understanding of the concept, as Participant 2 demonstrates in expressing a definition of biodiversity that differed from the definition presented by the exhibition. Buijs et al. (2009) reports that individual definitions of biodiversity are affected by a wide array of related concepts, such as "nature" and "landscapes". These are useful in "anchoring representations of biodiversity" (Buijs et al., 2009, 70).

In this study, we found that the analyzed exhibitions allowed for deeper reflections on these definitions and offered novel insights to their visitors. For example, the role of science (and museum research) in classifying and cataloging species was notably commented on, with references made to the importance of the collected specimens to progress in the natural sciences.

References to the scientific procedures of collecting, cataloging, and systematizing collections of specimens were made by all of the participants, and our inductive analysis showed a clear focus on scientific perspectives in the participants' perceptions. For example, Participants 2 and 4, when describing the exhibitions, emphasized aspects

of the cataloging system, such as:

Participant 2 *'(...) when you open those drawers and have each insect registered, classified, then you can have an idea of the work to catalog, to conserve each species. (...) so when I opened a drawer it had this cataloged, the code (...)'* (Interview)

Participant 4 *'(...) I like those with drawers, and you can pull them and see all individual species. (...) you can see more details, the exact individual species, especially when they have a real sample, you know, a preserved real sample, not just a replica. So, you see on a very micro level all the details of each individual species'* (Interview)

Analysis revealed that, for some participants, definitions of the term biodiversity were built using generalized arguments related to the concepts of species diversity and differences of individuals, such as the “diversity of living things” (Participant 6); ‘diversity of many species living in the same ecosystem’ (Participant 3); and ‘different species and ecosystems’ (Participant 2).

Such comments outline the scientific and rational attributes associated with the definition of ‘biodiversity’, demonstrating the presence of the logical reasoning STSE current, which highlights the presence of concepts, classifications, and empirical evidence, focusing on science itself and lacking references to any social context. In these cases, the participants’ expressions of their perceptions of biodiversity were grounded in their own explorations of scientific information and data, something not characteristically observed in the other STSE currents.

Theme 2 – Biodiversity Values

This theme focuses on participants’ perceptions in regard to aspects of human values and how they relate to impacts on biodiversity. The relationships between living things perceived by the participants were linked to ecology and the environment. The participants expressed through dialogue their views on the values of different groups of organisms such as animals and plants, as well as differing views on who bears responsibility for the “Crisis of Life” and criticism of human activity in nature. Sometimes, they also express their opinion, agreeing or disagreeing about what the exhibitions brings and, make reflections about that.

Participant 1: *'(...) animals are in crisis, Ok. This idea is also interesting, because it is saying that biodiversity is in crisis, but in reality, what is in crisis is, like, life existing all together. And, it is almost as if we have put the crisis on them (the animals) and now we are saying that they are in crisis. It is a little problematic to do this, because these animals are incredibly diverse, adapting to the fact that we are destroying their environment (...), but I think it is humans who are really to blame (...)'* (Interview)

Participant 7: *'(...) a lot of people say that they don't eat the animal because it is alive (and) they forget that vegetables are alive, despite being still. (...) what do you think: that putting the ax to a tree is human?'*

I mean, then, the lack of knowledge leads to certain assertions that people have, that they do not (...) perceive, but that they have. (...) biodiversity is not static, and it is not because a species goes into extinction that the effect of it going into extinction was caused by someone (...). It is caused by the whole environment, by every adversity of the environment'. (Interview)

Participant 6: *'(...) like, you could just watch a video, why do they (referring to zoos) have to bring elephants from India to Canada, where it's so cold? (...) at the museum it is more, it is a little more ethical, I think. (...) because maybe they (the museums) took, with luck, some animals that died, so they just reused the body or, you know, were confiscated from people who are negotiating, or something like that, thinking about how there is no waste, teach people about it, that's good, but kill it for ... (...) the closer the animals get to humans, the more threatened, the more they are in danger, right?'. (Interview)*

These comments highlight relevant aspects of the relationships between living beings in nature, as they shed light on the different roles played by human beings: sometimes as part of nature and suffering from the changes it undergoes, sometimes as responsible for destroying it, demonstrating characteristics of the experiencing the natural environment current proposed by Steele (2014) and the sociocultural and value-centered currents proposed by Pedretti and Nazir (2011). Novacek (2008) argues that when individuals reflect on biodiversity, their responses tend to emphasize efforts to protect biodiversity and concerns regarding habitat destruction. It is noteworthy that some participants related these concerns to the role of humans in the environment.

For example, Participant 1, on mentioning that “[...] and, it is almost as if we have put the crisis on them (the animals) and now we are saying that they are in crisis”, demonstrates reflection on the effects of human activity on biodiversity, employing the perspective of the value-centered STSE current. Steele (2013) comments that strategies characteristic of the value-centered current draw attention to socioscientific issues (those which have a direct impact on society) from an ethical perspective. This type of reflection is implicit in Participant 6’s statement “the closer the animals get to humans, the more threatened, the more they are in danger, right?”, while it also maintains connection with the experiencing the natural environment current, especially in reflecting on how human beings should interact with nature (Steele, 2014). This also indicates the importance of understanding and interpreting the environment using constructed sociocultural knowledge, which coincides with elements of the sociocultural STSE current.

Participant 3, for example, emphasized recognition of life as being in crisis and of human beings as an integral part of the environment, as well as of the relationships established between society and the environment in the following comment: ‘(...), when they say, for example, the giant tortoise, (...) it is not that it is being directly hunted, but it is the victim of bycatch, or also a panda when the forest where it lives is destroyed, it dies. Many examples that a species is killed and then ends up affecting another ... like this’).

Participant 4 corroborates this perception when he mentions that humans are causing the observed impacts and changes in the environment, as in the cases of climate change and the introduction of invasive species. These comments reinforce the importance of the relationships between living beings in nature as they recognize the role

of human beings in biodiversity loss.

It was evident that the recognition that human beings are an integral part of nature, interacting, impacting, and being impacted by the environment in which they live, triggered affective, emotional, sensory, and intuitive learning. This centered around the concept of a deep and permanent bond between humans and nature, in which science represents a key resource that humans have developed in order to interpret their environment. That being said, the participants expressed differing views on humanity's position in this relationship, with some describing humanity as part of nature and some as exterior to it and responsible for destroying it.

Several of these affective and emotional reactions provoked by the exhibitions appeared in the interviews. Participant 3, when asked about a panel that mentioned global warming as causing glacial melt, cited a polar bear on display in a shop window, saying: 'Ah, it's sad, right. Then (you) remember the image of the polar bear falling from a piece of ice, the last one he was standing on. So, the polar bear is kind of an icon like that, because it is a giant animal, you see its fragility and it is very impactful' (Participant 3). Considering the characteristics of the exhibitions, we understand the statements made by Participants 3 and 5 as being related to the experiencing the natural environment and value-centered currents, supporting engagement in interactive activities in addition to arousing emotions and affectivity.

Some participants, when asked about how they would describe ROM exhibitions to a friend, emphasized the relationship between preserving biodiversity and Life in Crisis. Participant 6, for example, emphasized the exhibition's ethical aspects, especially in regard to the use of animal specimens and methods employed in acquiring these specimens for the exhibitions. Expressing their concerns regarding the 'relationship between living beings in nature: the different roles of human beings', Participant 6 expressed a view of human beings as dangerous to animals.

This theme allowed for us to appreciate the alignment of participants' perceptions with the characteristics of several currents, for example the sociocultural and value-centered currents, in which STSE relationships are embedded in an indivisible context of citizenship, moral and ethical responsibility, and the preservation of nature that is acted out through the actions of human beings in the environment. Characteristics of the experiencing the natural environment current were also identified, especially in regard to the way in which the exhibit brought visitors closer to the natural environment and in the affective and emotional aspects that the exhibits offered, as in the case of the polar bear narrated by Participant 3.

Theme 3 – Activism and Biodiversity

Perceptions categorized under this theme center around scientific debate and sociopolitical considerations. This theme's perceptions emphasize real-world interventions intended to create transformational change and raising awareness of environmental issues as worthwhile goals. Some participants highlighted the importance of including the themes of individual and social ethical responsibility in museum exhibits on biodiversity, demonstrating the perspective that societal science-related decision-making must take STSE relationships into consideration as it is

not exempt from moral and ethical considerations.

Participant 6: *'I was asking about ethics. How they (museum staff) have this (preserved biological preserved objects presented in a cart). And, they were just sharing with me that they managed to get it through, someone offered, they took it at the border, someone tried to sell it and, it is sold from museum to museum, so ... It is interesting to touch, I think it is not worth it, like this, for monetary gain, I think it is not worth it, if you could make a replica, then you don't need animals to be killed because of that'.* (Interview)

Participant 4: *'(...) through it (ROM) I felt that as a space it is more neutral. So, maybe (the relation is) not ROM and society, but science and society, of course (...). From my background, my perspective, I think 'yes', there is a connection and a very significant impact on science and society, there are so many other factors that impact, like, social, political, economic, on how society perceives science, how science develops, so I think (that) yes (...)'.* (Interview)

The museum, to these participants, was considered to be a scientific institution with social, political and ethical responsibilities regarding the collection, research, and presentation of biodiversity to its audience, perceptions that correspond with aspects of the sociocultural and socio-ecojustice STSE currents. As mentioned by Pedretti and Nazir (2011), the socio-ecojustice STSE current suggests that criticizing and working to solve problems caused by human activity is more important than simply understanding the impacts of science and technology on society and the environment. In keeping with this sentiment, the authors distinguish this current from the others by arguing that “advocates of this current believe that traditional science education and other STSE currents do not go far enough in educating students about the political and economic factors influencing science and science education, nor does it provide them with the necessary tools to actively transform society” (Pedretti and Nazir, 2011, 617). They go on to add that, in this current, science and technology are described as based in the social and cultural contexts in which they occur, which is also a characteristic perspective of the sociocultural current.

Discussion of the museum's collections led participants to a perception of civic responsibility and the importance of considering the implications of STSE relationships in everyday life, represented in statements such as: ‘stop destroying the planet’ and ‘think about it as critically as you can’

Participant 1: *'(The Schad gallery) starts by saying that life is diverse, life is interactive and interconnected, and then life is in crisis. Although I believe that these three messages are incredibly important to convey to the public, there is still something (...) (that) I would recommend, based on that. I would still say to someone who goes there (at the museum): "think about it as critically as you can.'* (Interview)

Participant 4: *'(...) It was very clear, everywhere (in the exhibition), that life is in crisis, that humans are causing this, I think that the exhibition is trying to show the value and the importance of the environment, biodiversity and the ecosystem, and how humans are affecting it, because everywhere it was (...) how*

humans are impacting: (...) changes in species, changes in the environment, climate change, overfishing, overpopulation, introduction of invasive species (...). (Interview)

Participant 3: *'(...) it is very sad because the exhibition did not show an alternative to change that (global warming) (...) we actually already know what it should be: it would be to 'stop destroying the planet'. Only it won't happen anytime soon. (...) that's right, I don't know, one would have to explain it: 'Stop destroying the planet!' Also, it is not you and me that are destroying the planet'*. (Interview)

The participants drew attention to an important goal in recognizing that visitors must develop a critical view not only of the biodiversity crisis but also of the exhibition's content and proposals, being compelled to "choose a side" and question their own viewpoints while reflecting on the role of the human beings in that scenario.

Arguments that stand out from these dialogue excerpts highlight a view that democratic principles bestow science as an institution with the responsibility to actively promote political action and dialogue between itself and society, demonstrating an interdependence between science and politics. This view is intrinsically related to the foundational elements of the socio-ecojustice and sociocultural STSE currents, which propose and defend the concept of "science for all" and the possibility of knowing and interpreting the environment in which we live. This application of democratic principles is typified by such actions as confronting and seeking solutions to issues arising from STSE relationships, such as global warming and deforestation. Participant 6, for example, noted that all human action affects nature and vice versa, or, put differently, that we are all interconnected all the time. For them, contemporary society is witnessing multiple ongoing crises: deforestation for the purposes of land development and construction, excessive fishing and pollution, overcrowding, scarcity of food, and low quality of life, among others. In this context, Participant 6 expands on a question posed by the exhibition: 'Is biodiversity important if humans do not benefit from it?', rhetorically responding: 'Of course it's important, we don't have to benefit from everything (...) there is a dark capitalist side to it (...) regardless of whether it's monetary or not, it's scary because we have children, they will have children, we have future generations to take care of' (Participant 6).

Participant 6's statements were motivated by questions about different expository elements, including a list of organisms at risk of extinction, phrases from the exhibition such as 'Global climate change is causing Artic ice to melt' an aquarium, and a coral reef, among others. Observing these exhibition elements generated discomfort in Participant 6, which occasioned several reflections on STSE relationships and their consequences regarding the maintenance of the planet's biodiversity. In particular, the participant emphasized the influence of capitalism at the expense of biodiversity, criticizing and reflecting on the socio-political issues that guide human activity, be it due to consumerism, unrestrained capitalism, decision-making processes, or human values. In general, museum exhibits on biodiversity tend to dazzle visitors in order to remind them of the beauty and wonder of nature as a form of communicating to the visitor precisely what is at risk (Novacek, 2008). However, aspects related to the political, economic topics and to the impacts on biodiversity are rarely exposed in museums, even the research about those topics are increasing (Kato, 2020).

The exhibits at the ROM, including Hands-on Biodiversity and Biodiversity: Life in Crisis accomplish this goal, but they also portray human activity and “contributions” in no uncertain terms as the crises’ principle causative factors, be it through lack of awareness or the implementation of public policies that negatively affect the environment.

The points made by some of the visitors reflect their view that it is not enough for an exhibit to criticize certain aspects of human activity, and that it is important to search for solutions for and raise awareness of socio environmental problems. These views are aligned with the characteristics of the socio-ecojustice current, as they affirm that scientific knowledge is inseparable from social, political, and economic values and conditions.

In closing, the data revealed that the participants took a critical stance on the biodiversity crisis, articulating their points of view, asking questions, and reflecting on the role of human beings in these scenarios. However, some of the participants desired to go further! For this group of participants, exhibitions should take a harder and more explicit stance on the idea of Life in Crisis and the impacts of humans on the environment. Participant 1 expresses this sentiment in the following comment: ‘it is important to address the role of humanity more completely and objectively, because I never felt there (in the exhibition) that I was being treated as the cause of these things (...)’, later adding that ‘anthropocentric climate change’ should be addressed more intensively by the exhibitions, broaching issues related to agriculture and the effects of human activity on climate change, on animal habitats, improving extinction risk for species such as the black-footed ferret.

Concluding Thoughts

In this study we sought to establish an understanding of whether and in what way STSE relationships were perceived at exhibitions on biodiversity at a science museum. The study participants’ reflections, analyzed through the lens of our three synthesized themes, demonstrated that participant perceptions were concerned as much with the conceptual and interpretive aspects of the exhibits as they were with ethical values and their relationship to biodiversity. Perceptions defending concrete environmental conservation initiatives were also numerous. In total, characteristics of five of the seven STSE currents were identified, being: logical reasoning, value-centered, sociocultural, experiencing the natural environment, and socio-ecojustice.

The application/design and historical currents were not identified in our analyses with regard to the participants’ perceptions of STSE relationships at the studied ROM exhibitions. The logical reasoning current was strongly present in the statements of all seven participants, especially when discussing their perceptions of biodiversity during their visit. For the participants, biodiversity was perceived from a foundation of empirical evidence that was accessed through the texts and other expository elements on display at the exhibitions. This form of understanding the world mirrors the epistemological approach of the sciences themselves to an extent, distancing itself from alternative interpretations such as socially based ones. McGuire and Tuchanska (2013, 152) comment that the epistemological approach “decontextualizes science, separating it from its real socio-historical context [...] deconstructing it in such a way that its complex social and historical totality is reduced to a preconceived notion of what scientific knowledge is how its development occurs.” This was a noticeably present perspective in

analysis of the first theme.

Other currents, specifically the value-centered, sociocultural, and socio-ecojjustice currents, were identified to a somewhat lesser extent, and were not restricted to a single theme. This finding corroborates Pedretti and Nazir's (2011, 619) assertions that "some currents can also coexist, overlap, and be utilized in harmony". They also articulate that characteristics of the sociocultural current are interrelated with aspects of the socio-ecojjustice current, especially in sociological approaches, though distinctions remain, as "the first focuses on the sociocultural aspects of science and science education [...] The other takes on the sociopolitical aspects of science and science education [...]" (Pedretti and Nazir, 2011, 615).

The authors also identify the socio-ecojjustice current's ability to motivate students in scientific learning as one of its key strengths. This is achieved through its propensity to demonstrate the importance of scientific knowledge to the wellbeing of society at large (Pedretti and Nazir, 2011). These dynamics can be inferred from the perceptions expounded by the participants of this study as well, especially those under the third analysis theme.

Another noteworthy finding was that the majority of the participants saw the museum space as an appropriate environment for the discussion of issues such as biodiversity loss and the crisis of life, as the museum is "an educational space" (Participant 6). This was not a unanimous perspective, however, as there were also visitors that questioned the appropriateness of raising such discussions at museums. This opposing sentiment is exemplified by the comment "this discussion shouldn't be [...] in the museum, it should be in the academic or political sphere, where these types of decisions are taken" (Participant 3). Other participants expanded on this viewpoint by mentioning, for example, that the idea of life in crisis should not be restricted to museums, despite recognizing museums as an important environment for science communication initiatives in society.

In this context, Participant 5 argued that, for her, the museum represented an initial invitation to reflect on Life in Crisis, and that it is essential to apply the knowledge gained in this space to one's everyday life, as this would yield important results for society. She also stated that she wanted to see more connections: 'I think it is most of... what we learn here, and apply those ideas (...) how do you take what you see here and the message you see here (...) and apply it to your daily practices and habits and other things?' (Participant 5). In regard to this sentiment, other studies have argued that the most effective and penetrating messages on biodiversity are those that clearly link scientific insights on biodiversity and biodiversity loss to more general environmental problems and, rooted in common experiences, to the day life of the public, for example, in the cases of deforestation, water quality, and invasive species, among other issues (Novacek, 2008; Seippel et al. 2012).

The individual and collective decisions made about science and technology are based, in part, on the interpretations of the information to which decision makers have access. Cerati and Marandino (2013, 772) argue that, 'in recent years there have been a series of proposals for the expansion of the role of museums in society, showing that they are able to contribute to the development of different aspects of Scientific Literacy (SL)'. Appreciating the relevance of STSE relationships in museum spaces can be a promising way to expand the possibilities of SL. In addition, environmental issues like biodiversity are highly relevant and have great

discussion potential in regard to STSE relationships in science museums (Marandino and Soares, 2005).

In closing, it can be affirmed that the biodiversity-focused ROM exhibitions analyzed in this study promoted deeper understanding of some of the most important characteristics of STSE relationships, contributing to the development of scientific literacy in society. However, some important aspects were perceived only superficially by the participants of this study, as in the case of the sociocultural aspects of science and the notion that technology is a part of society. Thus, we reinforce Pedretti's (2003) defense of the need for scientific knowledge to be portrayed as a human activity, recognizing both the strengths and limitations of science and technology as well as the relationships they have established with the environment and with society. This is a movement that science museums must increasingly reflect and embody in their educational initiatives.

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Author Information

Pedro Donizete Colombo Junior


 <https://orcid.org/0000-0003-3324-5859>

Federal University of Triângulo Mineiro (UFTM)
Institute of Exact, Natural and Educational Sciences (ICENE)
Professor Aluízio Rosa Prata. Avenue Vigário Carlos, 100 - 5th floor - Room 538 Uberaba, Minas Gerais, 38025-180.

Brazil


Contact e-mail: pedro.colombo@uftm.edu.br

Martha Marandino

 <https://orcid.org/0000-0001-9175-012X>

University of São Paulo
Faculty of Education
Av. da Universidade, 308 - Butantã, São Paulo - SP, 05508-040
Brazil

Graziele Scalfi

 <https://orcid.org/0000-0002-1417-1287>

National Institute of Public Communication of Science and Technology (INCT-CPCT)
Avenida Brasil, 4365, 21040-900, Rio de Janeiro
Brazil
