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Children as curators: how to incorporate young visitors' voices into the elaboration and evaluation of a microbiology exhibition

Crianças como curadores: como incorporar as vozes dos jovens visitantes na elaboração e avaliação de uma exibição de microbiologia

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Abstract

Studies of museum publics are relatively recent, and studies of child visitors are even more recent. In this paper we summarize the types of exhibition evaluations mentioned in the literature and present an evaluation process for an exhibition about microbiology developed for and with input from 4-to-6-year-old children. As a case study we analyzed an exhibition entitled "The Giant World of Microbes." Audio and video interviews were recorded with child visitors, and the stimulated recall technique was also employed. The data indicate the importance of interactive activities in enhancing child motivation and providing pertinent routes to follow when preparing an exhibition geared toward children.

Keywords: young children; science museum; exhibition evaluation; microorganisms; scientific literacy.

Resumo

Os estudos sobre exibições em museus são relativamente recentes, e estudos sobre crianças visitantes são mais recentes ainda. Este trabalho faz um resumo dos tipos de avaliações de exibição mencionados na literatura e apresenta um processo de avaliação para uma exibição de microbiologia desenvolvida para, e com o auxilio de, crianças entre 4 e 6 anos. Como estudo de caso analisamos uma exibição intitulada "O Mundo Gigante dos Micróbios". Foram gravadas entrevistas de áudio e vídeo com os visitantes mirins, e também se utilizou a técnica de estimulação da memória. Os dados indicam a importância das atividades interativas no fortalecimento da motivação das crianças e oferecem caminhos pertinentes a seguir na elaboração de exibições focadas no público infantil.

Palavras-chave: crianças; museu científico; avaliação de exibição; microorganismos; literatura científica.

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The importance of informal settings for science education is widely recognized; important among these spaces are science museums and science centers, considering the growing number of publications that investigate the role of these institutions in science education. The objectives of this research are diverse, and include understanding the educational role of these institutions (Xanthoudaki et al., 2007), their potential in improving knowledge acquisition and changes in interests and beliefs (Schwan, Grajal, Lewalter, 2014; Kirchberg, Tröndle, 2012), their relation with formal spaces (Bobick, Hornby, 2013), the different forms of knowledge production within these spaces (Marandino, 2005), the importance of museum objects (Paris, 2009), interfaces with other fields of knowledge (Heering, 2017), as well as limits and challenges in strengthening the educational role of museums and science centers (Dawson, 2014).

Science museums in particular are becoming important locations for strengthening scientific culture (Bandelli, 2014). One of the important communication mechanisms used in this process by these institutions is long-term exhibitions, and evaluation of these exhibitions has become a powerful tool for improving the interaction between museums and the public.

There are several justifications for evaluating museum exhibitions. The idea of estimating the "effectiveness" of the displayed material on audience behavior and interest (and analyzing its interpretations) is recurrent. Such assessments also generate knowledge that can help museum professionals plan future exhibitions and programs to enrich visitor experiences (Munley, 1987; Screven, 1990).

Considering the importance and need to evaluate audiences and museum exhibitions, several authors have systematized and categorized this practice. Each author proposes unique definitions for each of the evaluation stages. In current evaluations, these stages are primarily based on information provided by visitors, which can be collected through interviews and audio and video recordings.

Munley (1987), for instance, lists four types of evaluation: formative, summative, process, and product evaluation. This author believes that formative evaluation occurs during the planning stage of the exhibition, and provides information about the effectiveness of the proposal. Summative evaluation takes place when the exhibition is ready, and is intended to verify the effectiveness of the entire effort, from determining whether the goals have been achieved to assessing crowd control techniques. This assessment may suggest the need for changes to the exhibit in progress or assist in planning new exhibitions. Process evaluation provides information about exhibition procedures, with emphasis on characteristics such as size, availability of a gallery guide etc., and indicates how these characteristics influence visitor learning and satisfaction. Finally, product evaluation focuses on how many visitors learn and/or change their attitudes.

Gottesdiener (1987), in turn, specifies that *préalable* or prior evaluation occurs before formative evaluation. This preliminary evaluation, which is linked to the exhibition project, involves collecting information such as the level of prior knowledge, difficulties related to the theme, and the attitudes of the target audience. This author also states that during formative evaluation, information about the effectiveness of the proposal can be obtained by presenting models or parts of the exhibit to the public. Although Gottesdiener's concept

of "summative" evaluation is similar to the one presented by Munley, she argues that the results can only be applied to new exhibitions without mentioning changes to the current one. Lastly, the author adds *"évaluation de l'évaluation*," which involves assembling and analyzing the recommendations made throughout the study.

Screven (1990) presents a type of evaluation that closely resembles the *préalable* evaluation described by Gottesdiener (1987) which he dubs "Front-End Evaluation," carried out before the exhibition design is defined. Likewise, both Screven and Gottesdiener suggest the same approach (using different names) for the final step, "remedial" and "*Évaluation de l'évaluation*," respectively. The attributions of remedial evaluation are found within the summative evaluation described by Munley, while Gottesdiener does not describe the possibility of modifying an ongoing exhibition.

In the same way, Cury (2005) postulates categories similar to those described by the aforementioned authors. Cury also details the process evaluation performed by the team responsible for exhibition design and/or execution, in which the aim is refining methodologies for work and planning techniques. This evaluation differs from the "process evaluation" described by Munley, which seeks to identify the characteristics that influence visitor learning and satisfaction, and possibly approaches Gottesdiener's *"évaluation de l'évaluation*." As the last category, Cury defines "technical evaluation or critical appraisal," which is carried out by the staff responsible for identifying unsatisfactory technical issues and assessing the design of the exhibition. This often involves assistance from external guests, thus differing from the "product evaluation" described by Munley, which evaluates how many visitors learned something during a visit.

To facilitate an understanding of how these evaluation approaches are related, each author's definitions for the different stages are summarized in Chart 1. It should be noted that this table places definitions that were similar among the different authors in the same line; where we determined that the meaning diverged, we chose to present them in different lines. The authors listed in the table were selected for this work because current studies tend to use similar names, for example Davies and Heath (2014) and Fu et al. (2016), who focus on summative evaluation, or Davidson (2015), who describes the different evaluation types.

Chart 1: Types of evaluation by author, organized according to similar definitions

Munley (1987)	Gottesdiner (1987)	Screven (1990)	Cury (2005)
	Préalable Linked to the exhibition project and involves collecting information, (for example, about visitors' prior knowledge, difficulties related to the theme, and attitudes of the target audience).	***Front-End*** Performed before defining the exhibition design. The purpose is to determine "correct" or "incorrect" concepts, as well as visitors' prior knowledge and interests related to the subject to be displayed.	***Preliminary*** Occurs while the exhibition is being planned, especially during the initial formulations and definition of the exhibition contents. Audience knowledge, concepts, interests, attitudes, and preferences are determined. Because ideas are evaluated, this step is also called concept evaluation.

Chart 1: Types of evaluation by author, organized according to similar definitions (cont.)

Munley (1987)	Gottesdiner (1987)	Screven (1990)	Cury (2005)
Formative Takes place in the planning stage of the exhibition, providing information about the effectiveness of the proposal. This information facilitates modifications by the organizer and designer to reach objectives.	***Formative*** Occurs when the exhibition is being prepared. The aim is to obtain information about the effectiveness of the proposal, by presenting models or parts of the exhibition to the public. Recommended modifications might be incorporated into the final exhibition.	***Formative*** Uses prototypes to examine visitor attitudes and reactions, and to determine which exhibits should be changed to improve communication.	***Formative*** Takes place during the early phases of exhibition design development, examining expographic resources through prototypes and simulations.
Summative Takes place when the exhibition is already open to the public. The purpose is to verify the effectiveness of the entire effort by determining how well the stated goals were achieved. The specific measurement of effectiveness varies from study to study. These studies may suggest the need for changes in the exhibit in progress or be of assistance in planning new exhibitions.	***Sommative*** Permits evaluation of the interaction between the exhibition and the public. Aspects like audience perceptions, preferences, attitudes, and learning are normally studied. The results of this evaluation can be applied to new exhibitions.	***Summative*** Analyzes the exhibition's degree of success in communicating its message. Strives to understand how the exhibition works as a whole, how the visitors interact with the exhibition, and what they learn from it.	***Summative*** Analyzes the interaction between the exhibition and the public via the proposed communication model. Helps formulate theories on how visitors learn and interact with a specific exhibition.
		Remedial Identifies how an exhibition which is already installed can be improved. However, significant problems found in this evaluation are often too expensive to resolve.	***Corrective*** Consists of almost immediate changes after unsatisfactory aspects of the exhibition are identified.
Process Provides information about the exhibition's procedures, emphasizing characteristics such as size, guide availability, etc., and indicates how these characteristics can influence visitor learning and satisfaction.			
	Evaluation de l´évaluation Groups and analyzes the recommendations made throughout the study.		***Process*** Performed by the team responsible for exhibition design and/or execution, and aims to refine the methodologies and work/ planning techniques.

Chart 1: Types of evaluation by author, organized according to similar definitions (cont.)

Munley (1987)	Gottesdiner (1987)	Screven (1990)	Cury (2005)
Product Measures and interprets the accomplishment of exhibition goals. These studies focus on how much visitors learn and/or change their attitudes after visiting the exhibition.			
			Technical evaluation or critical appraisal Conducted by the staff responsible for raising unsatisfactory technical issues and evaluating the merit of the exhibit design, often with the help of outside experts. Both the project and installed exhibition are evaluated.

Source: Munley (1987), Gottesdiener (1987), Screven (1980), Cury (2005).

Given the role of museums in advancing scientific literacy among children (Santos, Nascimento-Schulze, Wachelke, 2005; Unesco, 1999), evaluation of exhibitions is needed not only to determine whether the goals have been achieved in summative evaluation, but also to enable and ensure that the objectives are attained by carrying out preliminary and formative evaluations. As Lorenzetti and Delizoicov (2001) point out, scientific literacy helps children understand the world around them; one way this is accomplished is by enabling them to appropriate the language of natural sciences and their meanings. Dominguez (2001, 2006) maintains that children should approach scientific knowledge in a playful manner, since ludic activities are essential for them to organize their thoughts and express their ideas. Consequently, in order for scientific knowledge to be acquired, children must be given an opportunity to consider scientific themes by employing several languages (drawing, playing games, acting etc.).

The proposals of the aforementioned authors are closely related to Vygotsky (2000), who states that creative activity occurs through a connection between fantasy and reality. Therefore, the more experiences children have, the greater their repertoire is, which in turn feeds back into the creation process that is essential for development and learning. It should consequently be remembered that science museums are institutions that permit children to enlarge their repertoire of experiences, so that they can approach scientific knowledge and undertake their own imaginary creations.

Unfortunately, as pointed out by Carvalho (2013), monitors in some art museums do not feel prepared to guide children and even express resistance, believing that children do not pay attention and do not belong in the museum. On the other hand, this same researcher observed that children behave in an inquisitive and participating manner during their visit to the museum exhibition. Resistance to participation by small children on the part of museums is thought to have contributed to the gap in the literature on exhibitions

for children. For example, even though very extensive international literature exists on exhibit evaluation, as noted by Almeida (2005) and Davidson (2015), little is known about the contribution of the evaluation process towards elaborating museum exhibitions for 4-to-6-year-old children.

Even so, some authors have started to direct their attention towards the positive relationship between children and museums, and their work offers some clues on how to develop successful exhibitions for the youngest audiences. Oliveira (2013) notes the importance of children using their imagination when visiting art museums, emphasizing that children do not perceive a dichotomy between visiting a museum and playing in a museum, since play is their usual language for approaching culture.

Analyzing the interaction between adults and children during visits to an art museum, Moura (2013) observed that the monitors were very effective with small children, and attributed their success to some characteristics including the following: 1) The monitors paid attention to what the children said, and considered them capable of appreciating and understanding the artwork in the exhibition; 2) The children's previous knowledge was considered in the conversation; 3) Interaction between the children was valued; and 4) Language was carefully chosen to be suitable for children.

In an investigation of science museums and exhibitions for young audiences, Iszlaji and Marandino (2014) mention the importance of museums planned for children, since these places notably feature stimulation of imagination, playfulness and creativity, assuming that children will be protagonists in the interactions which occur. Specifically with regard to exhibitions for children in Brazilian science museums (including the "Giant World of Microbes" exhibition), the authors emphasize that despite science museums' increased interest in organizing exhibitions for small children, initiatives directed at young audiences are still isolated and face many hurdles in Brazil.

To serve numerous children up to six years of age who visit the Museum of Microbiology at the Butantan Institute, a new exhibition was planned and implemented. Qualitative and quantitative evaluations were performed during these processes, from conception to implementation. The premise underpinning the exhibition considered the children's understanding and expectations of microorganisms, consequently making the young visitor's voice a decisive factor in selecting the exhibits to be displayed in the exhibition. In this article, we present how the evaluation process can boost the engagement of 4-to-6-year-old children in developing and implementing a science museum exhibition.

Methods

Case study

To analyze the evaluation process, as a case study we selected the planning and implementation of an exhibition entitled "The Giant World of Microbes," which was geared towards 4-to-6-year-olds at the Butantan Institute's Museum of Microbiology. This is Brazil's only museum that predominantly features scientific communication of themes related to microorganisms, serums, and vaccines.

The museum team developed an evaluation proposal during the entire process of creating and implementing the exhibition. The stages of evaluation and data collection strategies are described below.

Evaluative stages

Based on the aforementioned conceptual framework, we developed and applied a four-step proposition (preliminary, formative, summative, and process) to develop the exhibition "The Giant World of Microbes," including time and costs required; the objectives, methods, and characteristics are presented below. It should be mentioned that this article primarily describes the results of how the evaluation process was carried out, regardless of whether the children learned anything about the contents of the exhibition.

a) Preliminary evaluation

This stage investigated what and how 4-to-6-year-old children think about microorganisms (in other words, their ideas and explanations about the behavioral and morphological aspects and biological interactions of these life forms) in order to help define the subjects to be addressed within each of these themes. We used the term "preliminary" (Cury, 2005) since this term is clearer than "front-end" or "*préalable*," especially in countries that speak Romance languages.

The initial proposal for the exhibition was an environment that simulated the rooms of a home to address the following themes: "microorganisms and environments," "scale and visibility," "health and hygiene," and "food."

During the planning of the exhibition, data for preliminary evaluation was collected in two different spaces: the Museum of Microbiology, and the Creche Oeste daycare center at the University of São Paulo (USP).

At the Museum of Microbiology, which children visit together with their families, 22 children were interviewed after obtaining parent/guardian consent to use the data and images. These interviews were videotaped, and held in a space that permitted conversation with the researcher as well as drawing and clay modeling. A handheld toy that magnifies objects up to 200 times and projects the magnified image on a TV screen was also installed in this space.

At the Creche Oeste daycare center, data was collected from a group of thirteen 5-year-old children after obtaining parental consent, during four meetings. The activities involved conversations about hygiene, discussions based on figures of the human body; the rooms of a house, and places in the daycare center, as well as readings of science diffusion texts.

The resulting data from both research sites was registered in a field diary. Audio and video recordings were preserved for subsequent transcription and content analysis. The collection of drawings and sculptures produced by the children was also analyzed.

b) Formative evaluation

The purpose of this evaluative stage was to analyze which types of exhibits and expographic options corresponding to the "learning environment" should be chosen to

better communicate the features of microorganisms to children and consequently are best suited for an exhibition directed at the target audience.

Twelve children visiting the Museum of Microbiology were interviewed as they handled exhibit prototypes such as fixed magnifying glasses, three-dimensional models of microorganisms (in resin and plush), and a handheld magnifying toy. Boards containing a variety of images of microorganisms (photomicrographs, simple, and anthropomorphized schematic drawings) were also presented to the children. All interviews were recorded in a field notebook, and the audio and video recordings were also fully transcribed for content analysis.

We opted to utilize the term "formative" as used by Screven (1990) and Cury (2005), who describe this step as taking place during the early phases of exhibition design development, with an examination of expographic resources using prototypes and simulations.

c) Summative evaluation

We developed a summative evaluation, as described by Munley (1987), Gottesdiener (1987), and Screven (1990). In the current study, this stage occurred after the exhibition opened and was intended to determine visitor interaction with the exhibition, for example what visitors learned and what changes took place in their attitudes. This was based on two distinct strategies: visit-behavior analysis and stimulated recall. In the first case, 4-to-6-year-olds (n = 54) were evaluated using an observational timing and tracking method according to the procedures proposed by Diamond (1999). Qualitative data collection was performed utilizing the digital audio and video recordings of conversations and digital photographic records of visit situations. Permission to use image and audio for research purposes was also obtained from the parents/guardians of all the children who participated in the research.

Timing and tracking records were analyzed, and then categories related to exhibit analysis which were modified according to Boisvert and Slez (1994) and Falcão (1999) were prepared as follows:

c.1– Attractiveness (considering visitors who looked at the exhibit for more than 3 seconds): Very attractive: visited by more than 80% of the children; Attractive: visited by 51–80%; Unattractive: visited by fewer than 50%.

c.2 – Holding power: Evaluation of the time spent with a given exhibit. If this was less than 5 seconds, the exhibit was considered "ignored."

c.3 – Revisit rate: Number of times the children returned to a given exhibit.

c.4 – Interactivity: The exhibit's level of interactivity was assessed according to the type of action performed by the children while handling each exhibit.

These actions were classified into three groups: contemplative, manipulative, and conversational.

The audience's voice was considered using the following categories:

c.5 – Conversational elaboration: Transcripts of the visit were graded according to the exhibition themes ("microorganisms and environments," "scale and visibility," "health and hygiene," and "food.") We also analyzed "learning-talk," as defined by Allen (2002), although this is not included in this current article.

c.6 – Stimulated recall. The stimulated recall technique (Falcão, Gilbert, 2005) was used as a second approach to evaluate visitor interaction with the exhibit; the purpose here was to stimulate recall by presenting pictures of exhibits. This technique was applied during semi-structured interviews, which took place on two different occasions, immediately after the visit (n = 36) and two months later (n = 5). In the latter visit, the children were shown images of themselves interacting during their visit. All the interviews were transcribed to facilitate conversational elaboration analysis.

d) Process evaluation

Similar to Gottesdiener's "*évaluation de l'évaluation*" and Cury's "process evaluation," in this stage reports and meetings analyzed how the evaluative stages described above influenced the choice of plausible options for exhibition design, and how these helped achieve the proposed objectives.

Results

Preliminary evaluation

This stage of the investigation determined that the team's initial proposal would be limited to those aspects of microbiology that most children already knew about, instead of scaffolding for broader concepts such as the role of microorganisms within the environment. Analysis of the data collected during the preliminary evaluation was consequently essential in redesigning the exhibition proposal. As explained below, the initial idea of simulating the rooms of a residence was completely abandoned.

Based on the assumption that the familiarity with the objects and themes in the exhibit could facilitate children's engagement during their visit, priority was placed on including various elements familiar to the children. One example is a game involving apples, which was developed after this evaluative step and addressed a recurrent element in the children's conversations, namely hand and food hygiene. Another game involved yogurt, and not only more deeply explored the topic but also introduced products like bread and cheese that, like yogurt, utilize microorganisms frequently cited by the children.

The collected data showed that most of the children spontaneously recognized the existence of something that cannot be seen with the naked eye, but few explicitly used the concept of scale, which confirmed the need to introduce this concept into the exhibition. Furthermore, although a few children made the comparison of "larger vs. smaller," most of them proved adept at handling magnifying glasses and understanding the power of magnification of these instruments. Taken together, these data reinforce the importance of an exhibition for this specific age group on the subject of microorganisms, using adequate instruments such as handheld magnifying glasses.

In graphic and verbal representations, although all the children presented microbes with morphological variations, half ignored habitat variations and only associated microorganisms with unclean areas in residences. We consequently decided that the theme of "biodiversity" needed to be addressed, and the idea of presenting microbes

in the home was abandoned. Children generally tend to only associate the existence of microbes with negative events. The theme "biological function" was included in the exhibition to move away from this good-versus-bad dichotomy. Few children make broader associations between microorganisms and humans and microorganisms and food, which justified including the themes "symbiosis with humans" and "food."

With regard to the intended goals of the exhibit, preliminary evaluation indicated that the original display setting proposed would not be the best strategy. Because children establish an immediate relationship between microbes and unclean places in the home, we opted for a new proposal in which different themes were presented in the same exhibition at different levels of understanding. This also included multiple forms of representing microorganisms (such as photomicrography, and simple schematic and anthropomorphic drawings), all of which are easily recognized by children.

While still emphasizing the maintenance and insertion of elements familiar to children, this new proposal introduced new aspects about microorganisms, such as their importance to the environment and role in food production. In some cases, the children's suggestions and demands were renegotiated with the executive team, which included multiple voices in the exhibition.

Our data were also consistent with the idea that visualization, manipulation, and playfulness are prerequisites to engaging children in this age group (4 to 6), so that museum visits can become experiences that enlarge their creative repertoire (Vygotsky, 2000). It may be difficult to prepare activities involving direct observation of microscopic organisms in early childhood education centers, and consequently science museums may be better suited for this task because of the nature of educational exhibits and material development at these institutions.

Formative evaluation

Data collected during a preliminary evaluation indicated that magnifying glasses should be included in the exhibition to help children understand the notions of image magnification and scale. But because some children did not spontaneously use the magnifying glasses during their visit, and consequently required assistance from educators, adults, or older children during observation, handheld magnifiers were added in the formative evaluation. These instruments are easy to handle, and the effect of magnification was easily perceived, even by children without previous experience using this equipment.

At this stage, the magnifying toy was also re-evaluated. Children found it very difficult to manipulate the toy properly and to clearly focus on the objects. Even when clearly focused, the device failed to communicate the idea of magnification, since the children did not associate the magnified image on the TV screen with the object itself. This led to a proposal to include a fixed microscope containing a small digital display in the permanent exhibition to facilitate the children's perception of device-produced magnification.

Among the three-dimensional models (resin or plush) the children indicated as being more similar to microbes, the evaluation found that the vast majority preferred the plush model, possibly because these are more common in the ludic universe of young children. When asked which model did not really resemble microbes, the choice was more random,

with both options used to represent diversity in microorganism shapes. Because the use of three-dimensional models proved attractive, these were included in the final exhibition.

Formative evaluation of the children's reactions to the prototypes gave a clearer understanding of what adjustments were needed to enhance the educational value of the exhibit. In Brazil, this type of evaluation is not usually undertaken by most professionals involved in designing exhibitions geared toward children. What is noteworthy in our research is that the children's voices were added to the exhibition, and by filling the spaces created for them provide a unique environment they can readily identify as their own. Additionally, by avoiding extra costs associated with future adjustments of the exhibits, formative evaluation has an important economic aspect.

The exhibition was redesigned and the content defined according to the results of evaluations conducted up to this point. A total of ten exhibits (or items) were designed to encompass the five thematic lines/themes redefined by the executive team (Chart 2), and the exhibition was named "The Giant World of Microbes." These exhibits incorporate diversity in expographic strategies, and consequently facilitate more in-depth identification of the items that attract children to the themes of the exhibition. In this way three-dimensional objects for handling interactive software, pictorial and audiovisual resources, and contemplative exhibits (corresponding to the "learning environment" of the investigation) were included in the new proposal. The premise of the educational practices proposed is to facilitate interaction within the visiting group, thereby emphasizing the importance of a more capable person in mediating between the child and scientific knowledge.

Chart 2: Items contained in the "Giant World of Microbes" exhibition

Item	Description
Sea	Film *Microbes even in the Sea* (duration: 1m50s) shown on LCD TV. Animated film using collage that addresses topics such as the food chain and photosynthesis.
Microscope	Microscope containing an LCD screen in place of lenses, showing living microorganisms in dirty water.
Fixed magnifying lens	Stereoscopic microscope (magnifying lens) showing tick larvae.
Forest	Film *The Forest and its Microbes* (duration 2m) shown on LCD TV. Animation created with collages addressing decomposition within the context of the food chain.
Ladybug	Panel with images of ladybugs and microbes (paramecium) at 100X magnification.
Apple	Interactive "Apple Game" on a touch-screen computer. After touching the screen a number of times, images of microorganisms appear on the surface of an apple, and options for eliminating them are offered.
Hand-held magnifiers	Hand-held magnifiers and a panel showing small images (such as postage stamps).
Yogurt	Interactive "Yogurt Game" on a touch-screen computer. The game presents yogurt, explains how it is produced with the help of bacteria, and offers options to discover other foods that are made with microorganisms.
Puzzle	Jigsaw puzzle with pieces in the shape of microorganisms: streptococcus, hexagonal virus, bacillus, amoeba, and paramecium.
Rubbings	Drawing activity in which crayons are rubbed over plates embossed with images of microorganisms to take a rubbing on paper.

Source: elaborated by the authors.

Summative evaluation

In observing the behavior of the audience visiting the newly installed exhibition, several aspects caught the team's attention, and measures were subsequently taken to adjust the installations in response.

Some items, such as interactive games and a fixed magnifying lens, posed certain difficulties because they require help from a monitor or adult. At the same time, children who had already learned how to use these items could teach other children or their parents. Based on observation of the visitors, a brochure was developed with information to help parents or guardians make full use of the exhibits and infographics introduced for children. Since one of the team's expectations was interaction and facilitation within the visiting group, this material was essential to include adults in the learning process for young children, and to help them better utilize the exhibits.

Further results of the summative evaluation emphasized poor acoustics, inadequate comfort, and handling problems with some objects. Measures were taken to correct these problems.

These changes were not considered as a part of a "corrective evaluation," as described by Screven (1990) and Cury (2005), who state that this type of evaluation constitutes a separate category and is carried out after the exhibition has been set up in order to change and improve unsatisfactory aspects. Our approach more closely resembled the perspective of Munley (1987), who does not define a special category of correction but includes these activities in the category of "summative evaluation," which occurs after the exhibition has already been set up.

a) Exhibit attractiveness

The criteria adopted to assessing exhibit attractiveness were determined by considering visitors who stopped and observed each exhibit for more than three seconds. The yogurt game (software) was classified as most attractive, with 88.9% visitation, and movies and fixed magnifying glasses were classified as very attractive (81.5%). Except for the ladybug panel, which was considered unattractive (5.6%), the remainder of the items were considered merely attractive (51-80%).

b) Exhibit holding power

All the exhibits retained the children's attention, since the median time spent with the items consistently exceeded five seconds. Because of the large dispersion of data (since few children interacted for long periods) and the fact that the sample distribution cannot be considered Gaussian, medians were used for analysis. The exhibits that drew the most attention involved crayon rubbings and the yogurt and apple games, which can be handled in various different ways.

c) Exhibit revisit rate

Calculation of the revisit rate, as a means of assessing the interest elicited by each exhibit, was based on visit repetition. Items with the highest revisit rates were the fixed magnifying glass, the yogurt game, and handheld magnifiers. These items provided more possibilities

for interaction: the yogurt game through facilitating following multiple paths, and the handheld magnifiers through the large number of small images available for viewing.

d) Exhibit interactivity

During collection of timing and tracking data, the children's actions during their time at the exhibition were recorded and described. All the items generated some form of visitor manifestation, and the exhibits can be divided into three types:

1. Contemplative exhibits, which solely stimulate observation: ladybug panel, microscope, ticks, and movies (sea and forest).

2. Manipulative exhibits which stimulating handling objects: jigsaw puzzle, the apple and yogurt games, crayon rubbings, and handheld magnifiers.

3. Conversation-generating exhibits, which elicited expressions and conversations related to the themes.

The number of actions carried out by children in each exhibit is presented in Table 1.

Table 1: Actions performed during interactions between 54 children and items within the "Giant World of Microbes" exhibition

	Contemplative	Manipulative	Conversation generators
Fixed magnifying lens	47	3	27
Jigsaw puzzle	4	26	13
Forest	45	0	47
Crayon rubbings	5	34	32
Yogurt	12	51	49
Ladybug	3	0	2
Hand-held magnifiers	5	39	24
Apple	6	35	57
Sea	44	0	38
Microscope	32	1	21

Source: elaborated by the authors.

e) Conversational elaboration

In conversations among family groups during visitation (n = 840), 251 references to the proposed themes were observed. Most common was biodiversity, followed by biodiversity related to human beings, especially health and hygiene. Among adults, biodiversity and biological function predominated. As for the structure of the conversation, based on the five main categories and 16 subcategories of learning-talk by Allen (2002), perceptual identification and strategic use were the most frequent.

f) Stimulated recall

The interviews held immediately after each visit showed that all the exhibits were recalled at least once. Recall was then correlated with data on the holding power of each exhibit. The

most remembered were the apple and yogurt games and handheld magnifiers. Calculation of the Spearman correlation coefficient, when including all points, yielded a value of r = 0.655, which represents a positive correlation between parameters. However, this coefficient increases to 0.7785 if data on the crayon rubbing activity (which had the longest median interaction time) are disregarded, since visitors spent more time on this activity than most of the other items. Yet contrary to what might be expected, this exhibit was the least recalled. In relation to holding power, recall of the films was also low; this was probably because the interaction time was determined by the fixed duration of the films ("Sea": 1m50s, and "Forest": 2m).

Process evaluation

This process was important to understand the correlations between the different evaluation stages (Chart 3). It was clear from the group meetings that a simpler evaluation process was required for the daily activities of the museum staff, which could simultaneously guarantee the participation of the various actors involved (mainly, the target public). This kind of evaluation permitted the development of a proposal that gives children a voice, which is essential when preparing a scientific exhibition for 4-to-6-year-olds.

Chart 3: Summary of evaluation processes and consequences for the exhibition design

Evaluation stage	What was analyzed	How it was analyzed	Consequences for the exhibition design
Preliminary	Prior knowledge	By identifying the children's conceptual repertory	They already knew scientific terms, and consequently were introduced to new content.
		By investigating familiarity with objects and themes	The proposal was redesigned to avoid associations between unclean areas and microorganisms. New aspects of microorganisms were introduced, such as food preparation and the role of the environment.
Formative	Prototypes	By assessing facility of manipulation and comprehension of image magnification and scale	Various degrees of amplification were included in the exhibition, since children were capable of understanding them.
	3-D models of microorganisms	By using several different shapes and material	Attractive and recognized as representing microbes
	Images of microorganisms	By using photomicrographs, and simple and anthropomorphized schematic drawings	Children recognized all the images as microorganisms
Summative	Installed exhibition	Attractiveness of the exhibits	Modifications to improve comfort and acoustics, as well as adequate material for better manipulation.
		Exhibit holding power	
		Exhibit revisit rate	
		Interactivity of exhibits	
		Stimulated recall	
		Conversational elaboration	
Process	The entire process of evaluation	Reports and meetings in which the role of each evaluation stage was discussed	Creating a proposal for evaluating a scientific exhibition that gives children a voice is essential for activities targeting 4-6-year-olds.

Source: elaborated by the authors.

Discussion

The data presented here clearly indicate that interactive activities most motivated the 4-to-6-year-olds to become involved in the exhibition, and were also the most attractive. The apple and yogurt games, crayon rubbing activity, and handheld magnifiers were the most attractive items, with the highest holding power, and with the exception of the crayon rubbing activity, were recalled the most after the visits.

It is important to note that the children did not fully explore some properties of the optical magnifying tools. Most felt uncomfortable with (or were discouraged from) handling the fixed magnifying glass, while the LCD screen of the microscope presented an obstacle to handling. In other situations, these devices might encourage young visitors to view the universe of microbes.

It is notable that while the timing/tracking protocol does not provide sufficient information to understand audience perception, important information can be obtained when the data are correlated, with other measurements, for example data on conversations and stimulated recall. In our opinion, the purpose of timing/tracking is to generate information related to the general perception of the exhibition, since the quality of interaction with an exhibit is more important than the length of time spent with it.

Corrective evaluation, as described by Screven (1990) and Cury (2005), was not carried out in this study. In fact, as recommended by Munley (1987), corrective action was carried out during the summative evaluation, since the information obtained at this stage can be used to introduce modifications.

Because of the greater possibility of interactivity, museum exhibits geared towards young children could be a driving force in bringing this audience into contact with scientific culture. However, further investigation is required to confirm the role of manipulative exhibits in scientific exhibitions for young children.

Lastly, we would like to highlight the key role of evaluation in all the phases of design and set up to guarantee the success of the exhibition. The effective participation of children – the target audience – was particularly relevant in this process, since exhibits for children are often based on adult ideas, without consideration of what children want or expect. The fact that the executive team gave a "free voice to children," for example, made it possible to redirect the initial proposal for the exhibition during preliminary evaluation so that the next stage (formative evaluation) already included elements the children considered important. Similarly, formative evaluation allowed the children to specify which types of exhibits were more likely to bring them closer to the world of microorganisms. Finally, summative evaluation again gave a "voice to children," who, upon interacting with the completed exhibition, showed which exhibits were the most attractive, had the greatest holding power, and generated more conversation. These data, combined with additional information obtained through stimulated recall interviews held immediately after each visit and qualitative analysis published elsewhere, were essential to our reflections about the most pertinent routes to address when preparing an exhibition for children.

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