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The giant artery: blood and blood vessels in a science museum

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ABSTRACT

In order to communicate scientific knowledge of blood and to raise awareness regarding physiopathology events occurring in blood, we describe here the creation and development of an art facility built at the Brazilian Science Museum. The installation reproduces a large human artery that visitors can walk through, designed to communicate several concepts about blood and blood vessels. It displays models of various cellular and molecular components and their characteristics: The mediation process uses analogies to express scientific content foster communication between the public and the concepts portrayed. Scenography techniques and features were used to produce models of actual blood components, including visual and sensory analogies and lighting. A survey was conducted in the form of questionnaires to 61 visitors; 99% of them very much liked the personal experience within the giant artery and 85% reported having a concrete learning experience with respect to some of the content. Our results suggest that the art installation communicates several concepts about blood and its components, conveying understanding of its characteristics and functions. The 'Giant Artery' provides visitors with a union of meanings characterised by scientific content and its associated emotions and sensations, finally resulting in an understanding of concepts.

KEYWORDS

Science museum; science-art; blood vessels; art-installation; non-formal education

Introduction

Interest in scientific knowledge has increased over the past several decades. The public seeks knowledge regarding matters that have direct relevance in their lives, including the global climate, genetic issues and health (Field and Powell 2001). An important health issue that attracts public interest is blood. Exposure to questions concerning diseases such as diabetes, atherosclerosis and hypertension draw the public to the universe of knowledge regarding blood. This interest can be used in science museums to promote awareness of the importance of blood donation, for example, to teach the characteristics of blood and its components, or to explain the occurrence of acute viraemia, bacteraemia, parasitaemia and sepsis. Education is a process of humanisation, socialisation and subjectivity, all essential elements for the understanding of scientific concepts (Ardoino 1980; Silva 2006). Non-formal education communicates with formal education through multiple

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**In memoriam

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Supplemental data for this article can be accessed here.

languages. Blood concepts are introduced in elementary school, and many teachers use interactive scientific models to aid content associations (Leenaars, Van Joolingen, and Bollen 2013).

Science centres and museums enable learning of specific contents using experimental and practical communication in a playful way (Pereira et al., 2008; Valente et al., 2005). The use of various artistic languages in these exhibits facilitates building relationships between the presented scientific content and the visitors' emotions and sensations, connecting new experiences to old ones, resulting in the understanding of abstract concepts from this encounter of meanings. They bring closer the individuals and the scientific knowledge translated to other languages by means of devices that link meaning and content of natural and technological phenomena. There is a consensus that science is a fundamental part of life and the education of contemporary man, and it must be accessible to all, both in physical and communicative aspects (Cavalcanti and Persechini 2011).

The representation of forms, and the way of representing them, leads the learning process through the observation of an object or a feature. The individual understands concepts via visual analysis and they rely on past experiences to confirm their findings. Ostrower (2010) relates the understanding of certain situations and actions to the human capacity for memorisation, storing the results of experiences throughout life. Resorting to these memories, individuals recognise similar situations or actions, consciously or unconsciously.

> In our consciousness, the role played by memory stands out. To man, it becomes possible to connect yesterday to tomorrow. Unlike animals, even those closest to the evolutionary scale, man can transcend the present, he can understand the present instant as the most recent extension of a past, which, when touching the future again, recedes and becomes past. From this lived experience he may retain certain passages and may guard them, with ample availability, for some unknown and unknowable future. Being able to conceive a development and a course in the flow of time, man can reformulate the intentions of his actions and can adopt certain criteria for future behavior. He collects from previous experiences the remembrance of results obtained, all of which guide him in possible actions requested in daily life (Ostrower 2010, free translation from Portuguese to English).

Ostrower (2010) stated that 'associations lead us into the fantasy world, generating our world of imagination. Associations generate an experimental world of thinking and acting on hypotheses – of what would be possible, if not always probable.'

Associations become possible through the joint work of memory and experimentation, and their main elements are perceptions of visual messages. Artistic language accompanies human relations with the world because of the development of language, and it is a primary form, essential for communication. Within the range of possible languages in the artistic dialectic, scenography meets the needs of science museums. The communication of a concept or content depends on the associations and analogies that can be made by the public. Scenarios are key icons for content transmission; however, it is necessary to establish criteria such that the visitor is reached in a meaningful way. The language of scenography is based on the representation of concepts through visual and sensory signs (Urssi, 2006). The scientific language presents contents through observation, experimentation and interactivity. Both search for meaning.

In Brazil, many students have no contact with experimental techniques or equipment at school and they rarely attend museums, including science museums. Schools alone cannot provide society with the world's scientific and technical information, because children and adults require permanent motivation and encouragement in order to learn (Constantin 2001; de Paula, Pereira, and Coutinho-Silva 2019). This reinforces the important role of both science and art museums as places of complementary knowledge for schools, in Brazil and abroad.

The science museum Espaço Ciência Viva (ECV), located in Rio de Janeiro, Brazil, uses various artistic languages associated with scientific content in most of its activities and workshops (Kurtenbach et al. 2004). We have previously set up a giant cell model in which visitors can find scaled organelles and discover cell functional and anatomical compartments (Araújo-Jorge 2004). Now, we conceived, developed and presented a 'Giant Artery.' To the best of our knowledge, it is the first such model in a science museum worldwide, an innovation that presents challenges and proposals for new media and understanding for scientific education.

Many educational contents are possible to be explored in this art installation, including (i) the behaviour and the main characteristics of the cells and the elements that make up blood; (ii) the characteristics of major cardiovascular diseases, atherosclerosis and thrombosis; (iii) the understanding the causes and propagation of infectious diseases and blood circulation of virus, bacteria and parasites and sepsis; (iv) the importance of blood donation and the ABO-system; and (v) the diversity and polymorphism of HLA genes and the importance of being a voluntary bone marrow donor, highlighting the importance of donation to occur, among other things.

In this report, we describe the conception, development and the initial evaluation of this model to understand the communication potential of the giant artery regarding blood and its elements to assist in the process of understanding its operation and its characteristics with various museum audiences. The methodology was performed using mediation and a semi-structured questionnaire, seeking to learn how satisfied the visitors were with the model.

Conception, design and presentation of the model

The context of the giant science art installation

In 2008, the ECV established a partnership with the Human and Experimental Biology Programme of UERJ (Rio de Janeiro State University), through the Histocompatibility and Cryopreservation Laboratory (HLA), together with Hemorio (a Brazilian public blood centre), to develop the project 'Science, Blood and Citizenship' with the aim of disseminating scientific knowledge regarding blood and its components, as well as the importance of donating blood and bone marrow. It was also designed to inform the public about the importance of healthy eating habits in order to avoid cardiovascular diseases. In the context of this partnership, this science-art model was conceived by the ECV team and was coordinated by the scientific director of the museum, Dr Karla Consort Ribeiro, together with students of scenography. A 'Blood Corridor' was proposed, composed of a scenography model 'Giant Artery', an 'Audiovisual Room' and the 'Multidisciplinary Laboratory of Sciences', all of which were physically connected environments (Gomes, Cardoso, and Kurtenbach 2018). The 'Giant Artery' (Figure 1–13) was inspired by the installation art entitled 'The Souls of Millions of Light Years Away' by Yayoi Kusama. The complete concept was developed after several meetings with science and artwork groups.

Development, installation and presentation

The 'Giant Artery' art installation (Figure 1) is adaptable to various scientific topics covered in the Espaço Ciência Viva, introducing models and representations of cells and other blood elements through symbolism and analogies. Scenography features were used to represent the functions and characteristics of blood components, including black illumination to highlight nuclei and membranes of the 'cells,' also highlighting 'molecules' (Figure 2) and an atheroma plaque (Figure 3). A variety of blood elements were reproduced for the model: red blood cells (Figure 4), glucose and alcohol molecules (Figure 5), calcium, haemoglobin, five types of white blood cells (monocytes, eosinophils, neutrophils (Figures 5 and 6), basophils, lymphocytes, platelets (Figure 5)), antibodies, other proteins and enzymes. To address situations that may occur in blood vessels, two spaces were designed within the 'Giant Artery': (i) narrowing of the passage at the beginning of the course to address the subject vasoconstriction and (ii) partial obstruction of the vessel at the end, describing how atherosclerotic disease (Figure 3) or coagulation (Figure 8) occur. The visitors can interact with all of these model components.

The 'Giant Artery' was built of masonry in a lateral corridor in the museum courtyard, measuring 8 m long x 2 m wide x 2 m high, with two doors, the entrance (Figures 7 and 9) that is accessed from the museum's interior and another door linking the model to an audiovisual room. To assume the circular shape of an artery, the inner wall of the model was coated with five

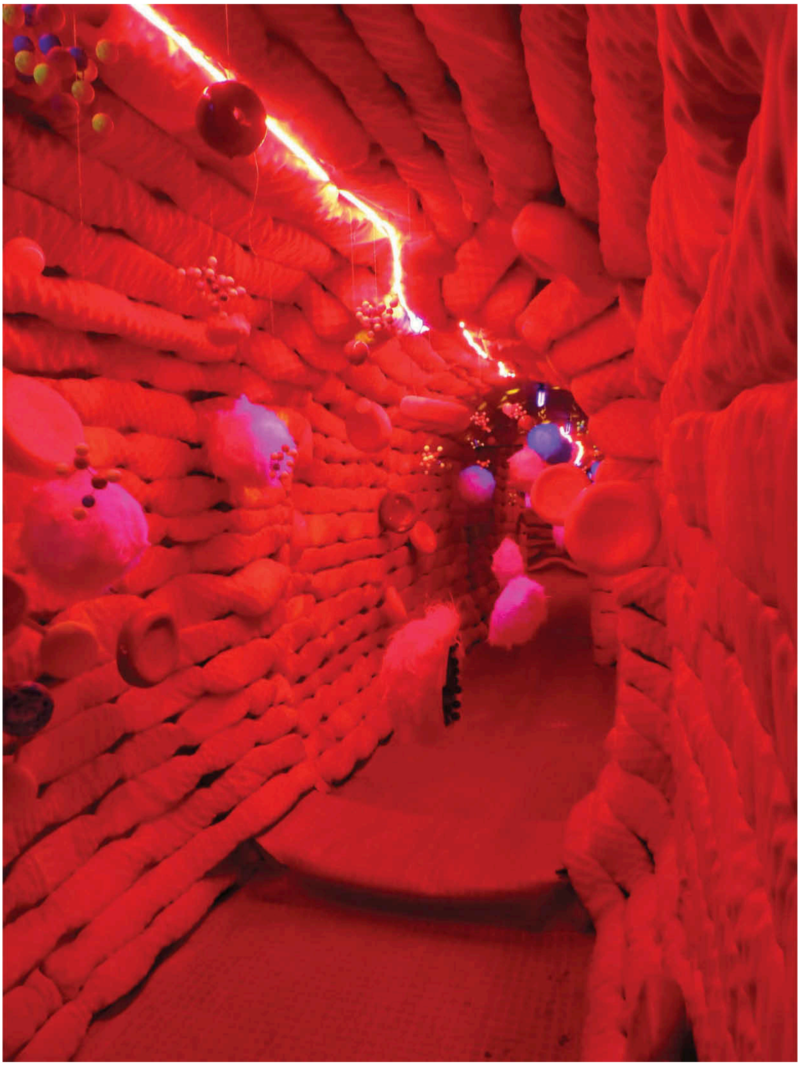

Figure 1. General inner view of the 'Giant Artery' Science-art installation at Espaço Ciência Viva, Rio de Janeiro, Brazil.

polystyrene (PS) plates (Figure 10). On the walls, a wooden frame was mounted to support the end of the plates, forming a 'circle' (Figure 10). The layers that structure the wall of the organ at the entrance door (Figures 7 and 9), about 50-cm thick, were designed to join the physical space with the characteristics of its contents. The use of physical space was a priority, because it is always in dialogue with the concept to be communicated. The scenography has, among others, the role of creating situations and adopting a dialogue with real space. This process is captured by the visitor when they become involved in the proposed context.

The set art science design team developed plastic models representative of the cellular and molecular components of blood (red blood cells, macrophages, glucose, lipoproteins, platelets) to make up the 'fictitious' blood (Figure 4–6). They were hung and distributed throughout the 'Artery,' making it difficult for the visitor to pass through (Figures 1, 2 and 4), causing them to interact with various components during the walking tour through the installation space. These components needed to be replaced and reviewed monthly by the team as they were used for the interaction of visitors with the model. Their durability was low because they could be touched and transported depending on the context. The size scale between the components was not strictly followed, due to an earlier decision to

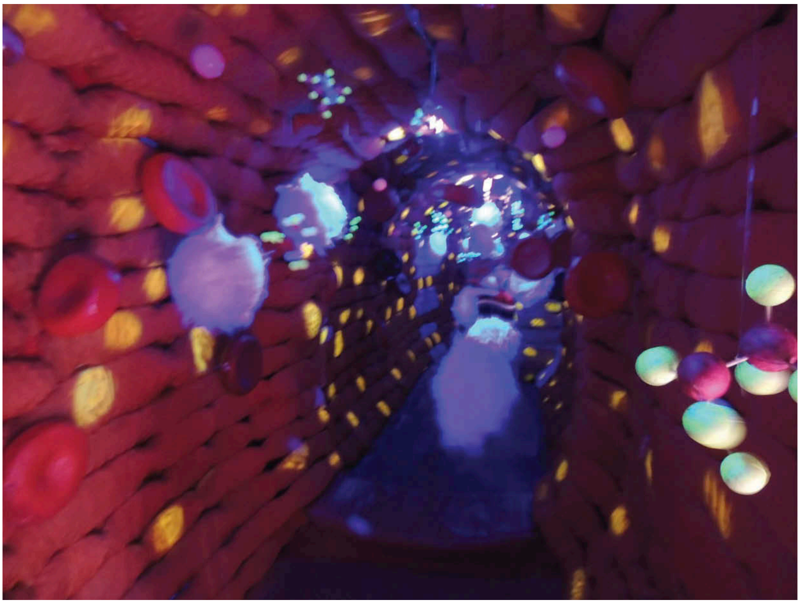

Figure 2. General view of the Giant Artery under black lighting.

Figure 3. Representation of an atheroma plaque inside the Giant Artery.

approach molecular and cellular structures in the same environment, making scale equivalence impossible. Nevertheless, at the cellular level, the scales were followed among the different blood cell types.

The inner circular wall was all coated, including the ceiling, with an orange foam covered by voile forming the 'endothelial tissue' of the artery/vessel (Figure 1). The floor was covered by a red rubber mat (Figure 1). A mirror, used as a scenic feature for depth illusion, has been attached to the entire wall, where the access door to the audiovisual room is aligned (Figure 11). On the wall opposite the mirror, the blood coagulation process was simulated (Figure 8), occupying the whole

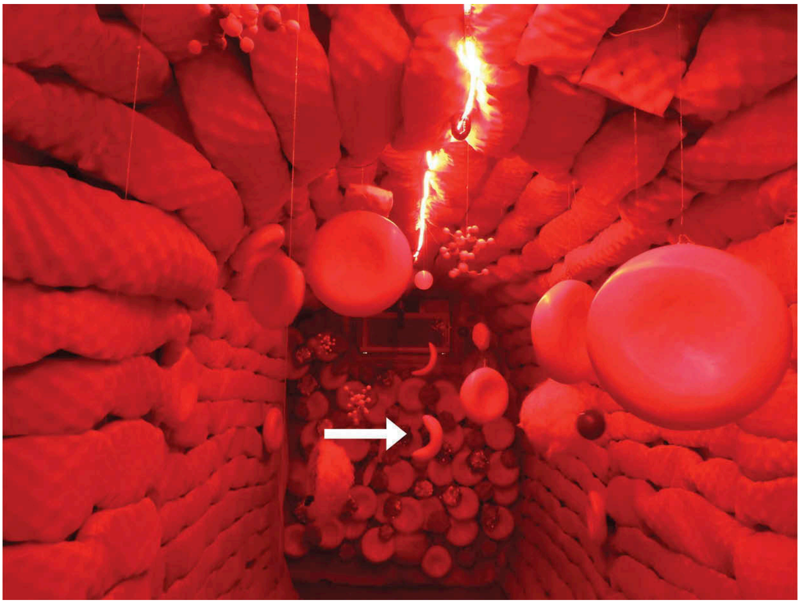

Figure 4. Representation of red blood cells, in normal shape and in falciform shape (white arrow).

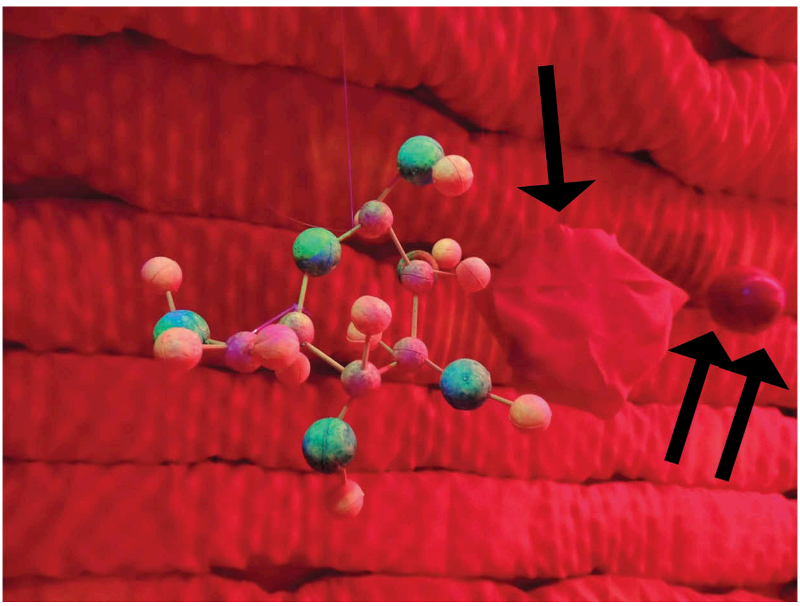

Figure 5. From left to right, representation of a glucose molecule, a platelet (single black arrow) and a lipid (double black arrow).

wall up to the top of the entrance door (Figure 7), also camouflaging the air-conditioning. It consists of a large amount of red blood cells and platelets, sheltered in a representation of the fibrin network. The structure encompasses the concept of the formation of a large clot due to the entrance of the visitors through a fissure in the internal wall of the artery (entrance door, Figures 7 and 8), involving the visitor to the microscopic context, where it was dimensioned to propose the immediate interaction with a model of a macrophage. A full general inner view of the model is shown in Figure 13, with an adult inside, allowing the idea of scaling the elements.

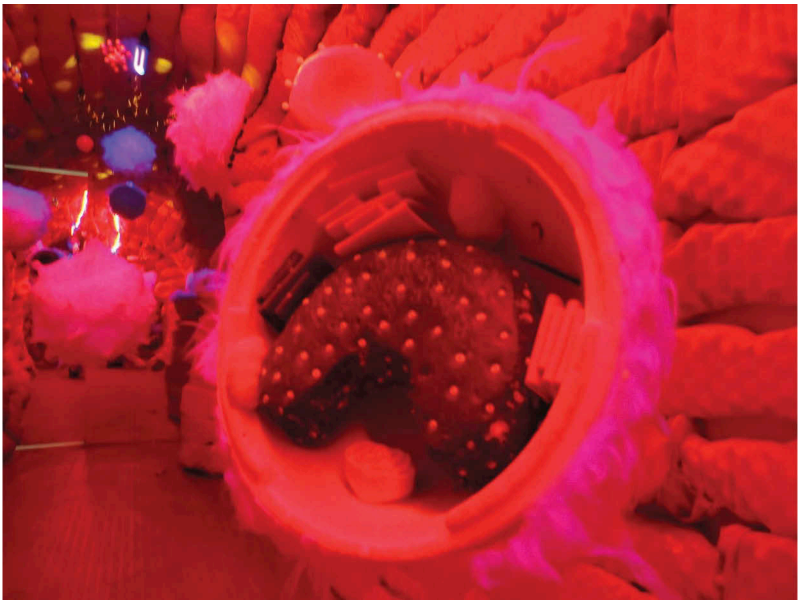

Figure 6. Representation of a white blood cell.

The ‘Artery’ has also been structured to approach atherosclerosis, process. The atheroma plaque was simulated with a foam and tissue structure that permitted less than one metre of space for visitor passage; it was filled with pool balls that mimic the lipoprotein molecules LDL and HDL (Figure 3) that clump together on the inner wall of the artery and are ‘ingested’ by the body’s defences, a process that is also represented by other features and analogies of scenography. This structure allows the visitors to dialogue with the model, placing and removing the ‘balls’ that represent the lipoproteins depending on the food itself. At that time, the mediator has the opportunity to work with the public on the relationship of dietary metabolism in the human body and cardiovascular diseases developed or aggravated by inadequate diet, showing the ratio between ‘good’ (HDL) and ‘bad’ (LDL) cholesterol lipid/fat carriers.

The model had two types of lighting, a red LED strip covering almost the entire length of the corridor (Figures 1 and 8) and three black light bulbs, distributed at both ends and in the centre of the artery. The red lighting is intended to refer the public to the colour of blood, and the black light is used to demonstrate conceptual features of the components such as cell nuclei, membranes and molecules prominent in the study of blood (Figure 2). After the inauguration of the model, the lighting underwent a physical modification that altered one of the artistic concepts of ambience. The red LED strip was configured with remote control that determines the movement of light, adjusted to simulate the heart rate for perception of heart beating. However, this effect disturbed some visitors, who reported vertigo from the intense movement in the closed space. The device was then removed, thereby restarting the static illumination set.

Participant experience

The art installation was inaugurated in 2013, and since then it has been fully operational, with more than 3,000 visitors interacting in a playful and dynamic manner, with language adjustments according to age group and types of audience. Small groups of 10 persons were permitted to enter the Giant Artery for 20-min experiences, thereby requiring previously distributed and numbered passwords Scenography was also integrated into the various themes of museum events, addressing other concepts in temporary representations. Mediation was rescheduled according to

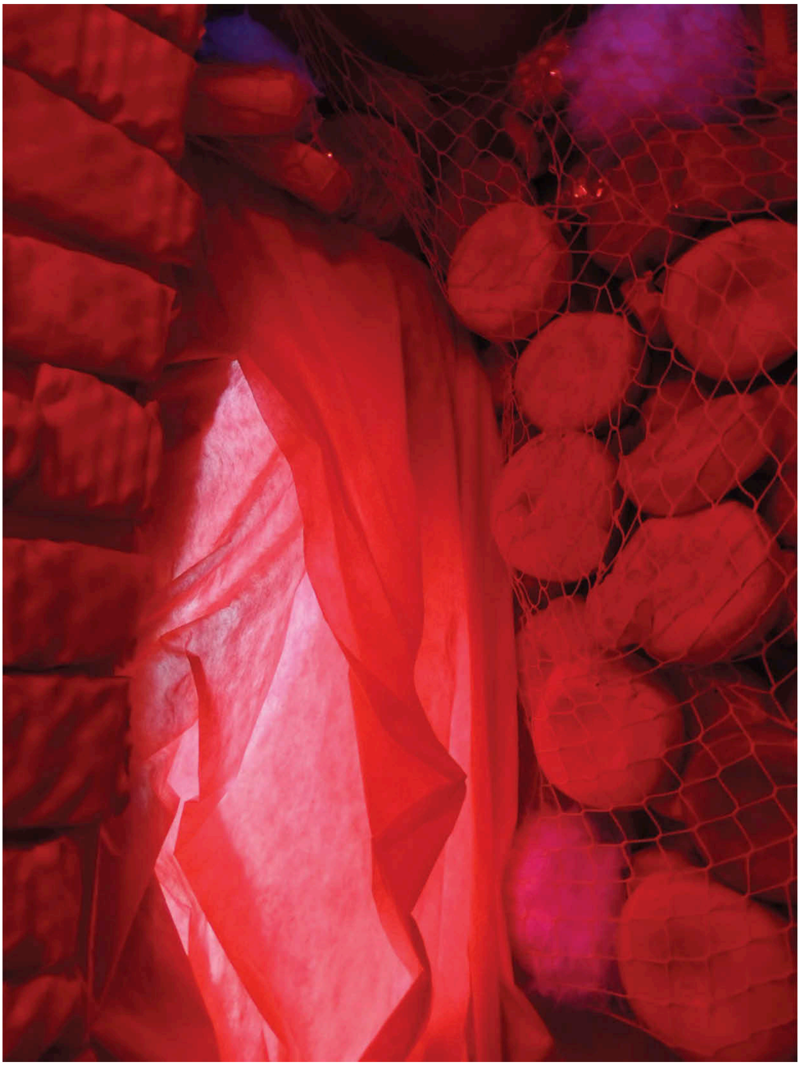

Figure 7. Inner part of the entrance door representing a cut in the vessel.

the changes in the scenario. The visit to the 'Giant Artery' model was integrated with the microscopy and experimental activities carried out in the attached biological laboratory, part of the same project that are not subjects in this present paper (Gomes, Cardoso, and Kurtenbach 2018)

The public enters the 'Giant Artery' through a slit (door) in groups guided by a museum mediator (Marandino, 2008). During the walk, the sound of blood passing through the artery is reproduced. Upon reaching the narrowed part of the model (simulation of smooth muscle contraction of the artery wall) the mediator may draw attention to the sound, making association with vessel circulation, raising issues such as blood pressure, breathing or falling and increasing body temperature. Illumination was arranged to approach red cells, cell nuclei and membranes, endothelial cells, molecules (glucose and alcohol) and lipoproteins. First, the mediator presents the blood coloured in red with red LED lamps, explaining the roles of haemoglobin and iron in oxygen transportation. In sequence, the black lights are turned on, highlighting the molecules, nuclei and membranes of cells, including endothelial cells. Then, the bloodstream components that have not yet been addressed are presented, including antibodies, sickle red cells, proteins, amino acids, and immune defence cells, distributed in five types by the model

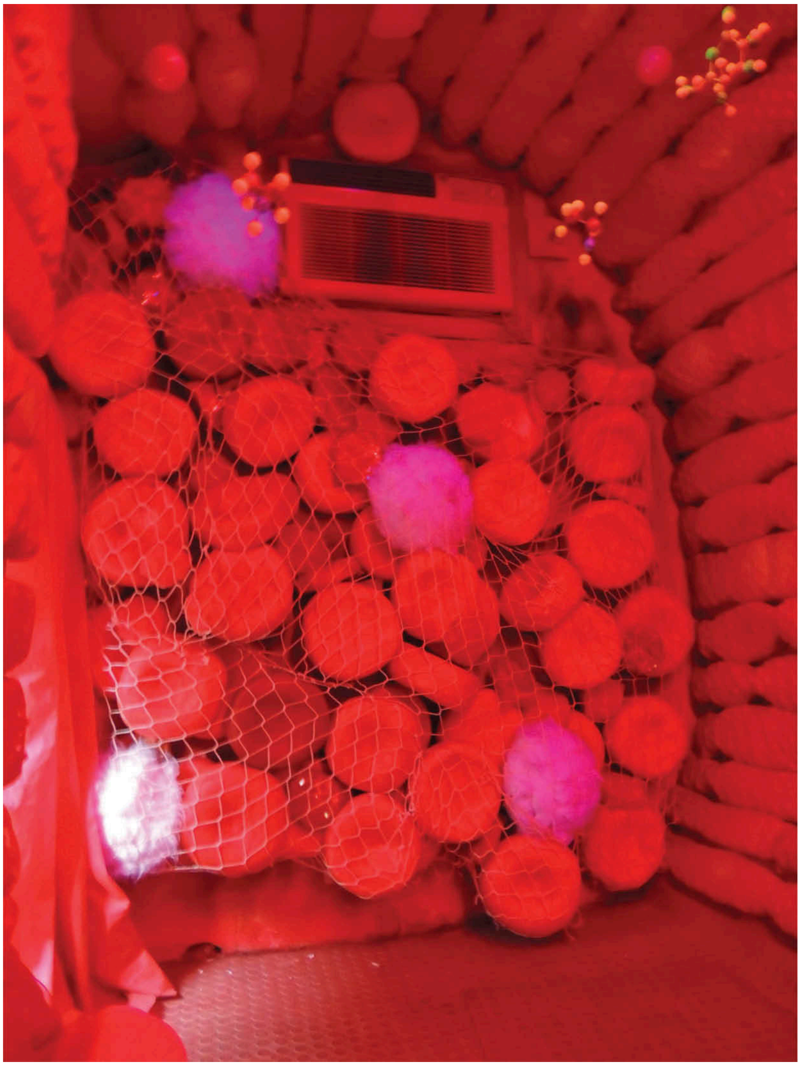

Figure 8. Lateral wall to the entrance door representing a clotting formation with a fibrin network.

(monocyte, eosinophil, basophil, lymphocyte and neutrophil). The pathway is the representation of an atheromatous plaque, causing partial clogging of the artery, where the mediator discusses the effects of and the body's reaction to the accumulation of dietary fat in the bloodstream on the artery wall, causing inflammation. The representation is filled with small blue and red plastic spheres symbolising LDL and HDL molecules, respectively low-density lipoproteins and high-density lipoproteins, where the visitors can remove and place spheres according to their interaction and to what is being discussed in the group.

Assessment

Public and data collection

Evaluation was performed in 2017 year with three different groups, each on a day of attendance, shortly after passed through the art installation. One of the groups was a school class and the others two were formed by spontaneous audiences of two different *Saturday of Science* thematic events that occurred at Espaço Ciência Viva (de Paula et al. 2015). The questionnaires were given to 61 volunteers visitors, aged 9 to 71 years: Group A (44 participants, 72% of the total surveyed public), formed by 9th grade students

Figure 9. General external view of the entrance door with representation of the inner layers of the artery wall.

and teachers, and aged 12 to 43 years; Group B (10 participants, 16% of the total surveyed public) formed by the general public visiting monthly the museum in the event '*Saturday of Science*' where the subject of the mediation was the 'Formation of an Atheromatous Plaque,' and were aged 17 to 52 years; Group C (7 participants, 12% of the total surveyed public) was also formed by the general public visiting the museum, however, on another *Saturday of Science* whose subject was the 'Sounds of the Heart', and were aged 9 to 71 years. *Saturday of Science* events usually receive an average of 400 visitors in the museum. Group A answered 96% and Groups B and C answered 98% of the questionnaire. Given that the model only holds a maximum of 10 visitors per session, mediation within the Giant Artery had variations between each session. Group A was subdivided into four groups to suit the maximum number of mediation sessions supported at the art installation. They were conducted with two mediators who interspersed their speeches throughout each session. Participants in Groups B and C did not know each other and participated in different sessions (eight sessions throughout). The total number of participants was different; however, the questionnaire administered was the same for the three groups. This is the reason we decided to present the results of the three groups separately, instead of summing them all. Nevertheless, the groups did not lend themselves to quantitative comparisons.

Figure 10. Phase of construction of the 'Giant Artery' using polystyrene plates.

The semi-structured survey questionnaire

We used a quantitative and qualitative research approach, characterised by seeking to understand the meaning that events and interactions had for each individual, to check the frequency of each type of answer in a given group and how they were expressed (Souza and Kerbauy 2017). The project was appreciated and approved by the institutional Committee of Ethics in Research. The questionnaire (Supplementary materials) was preliminarily validated with four visitors and in its final version consisted of three open questions; this was derived from a model definition by Root-Bernstein and Root-Bernstein (2001). Based on each of the four aspects described by these authors, we used items as parameters to develop the questionnaire to characterise the art-installation model as (i) *a communicator* of the scientific contents presented in its structure; and to determine whether the model met the requirement of (ii) *being representative* (item 01), with the main characteristics of the real visitor object being a real microphotograph image of one real white blood cell taken under a microscope (Supplementary materials). The first image was a glucose molecule with a structure different from that of a cell. The second image, considered 'correct,' was the representation of an

Figure 11. Inner wall with a mirror and the exit door, with the atherosclerosis spot at right.

'open' white blood cell, showing the interior of the cell, presenting characteristics like those of the microscopic images. The third image was an indicator for a possible association marking by the similarity of the shape, representing a red blood cell. The erythrocytes resemble white blood cells in that they are spherical, differing in the colour and in the absence of nuclei, as well as in whole dimension. These are contents worked in the mediation with the public during the discussion about the functions of the components represented in the art installation. The fourth image, also 'correct,' was a whole 'closed' white blood cell, not presenting its interior content (white blood cell 2), to assess the understanding of the three-dimensionality of cells and to associate this component with the real image, also content covered in the visit mediation.

Open questions

Item 1 was open question, and the answers were subjected to content analysis as described (BARDIN 2009), and categories emerged from this analysis. Item 2 requested the visitors to write something that they learned as new content presented during and/or after the travelling through the 'Giant Artery.' We intended to indicate the potential of this art installation as an effective model for

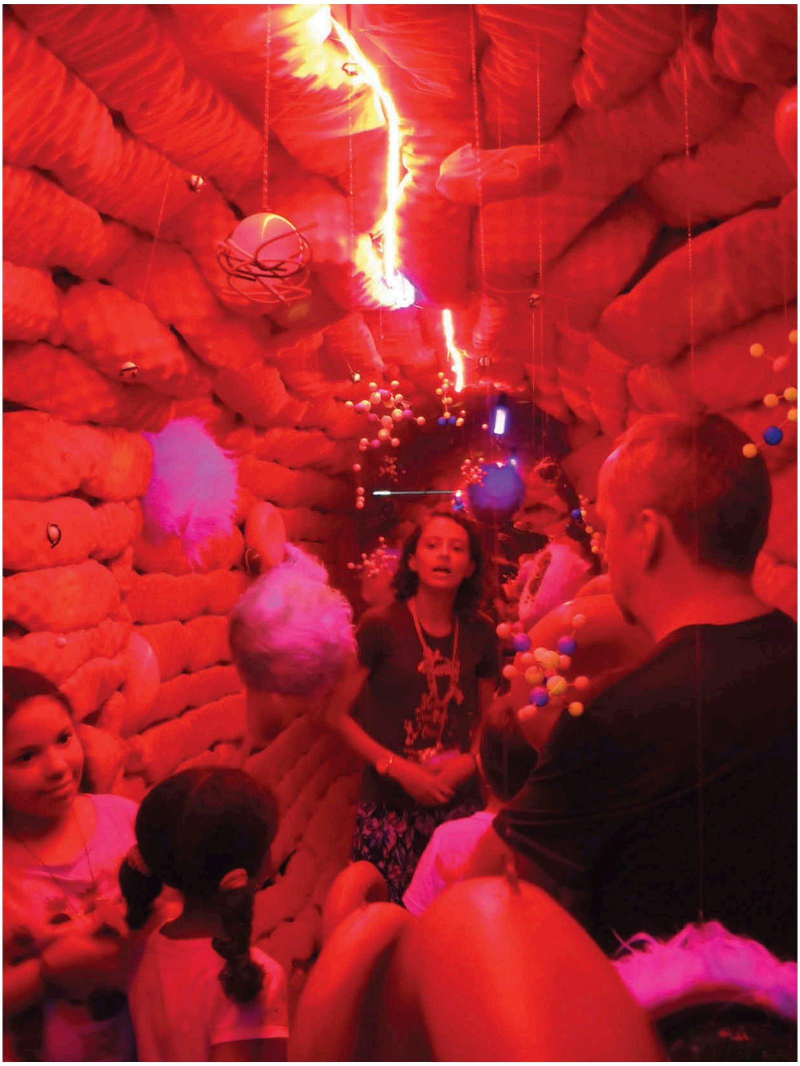

Figure 12. General inner view of the entrance door to show the scale for an adult inside.

learning based on the answers presented, becoming effective as a theoretical model if learning was reported. Item 3 asked the visitors to describe what were their sensations during the passage through the model, to determine whether the art installation could also function as an imaginary space, awakening dimensional changes in time and space. The words recorded were analysed using word clouds with the online tool Wordle.net that displays in picture form the frequency of appearance of each word proportional to its size. This provided qualitative evidence and emphasised the major sensations on the part of the public.

Finally, item 4 presented a general picture of the 'Giant Artery' followed by the proposition: in this figure, choose any component of the artery that has grabbed your attention and describe the role that you think that this element plays in the blood. The idea was to determine whether the visitor obtained any particular content proposed by the mediator during the visit and discussion inside the installation.

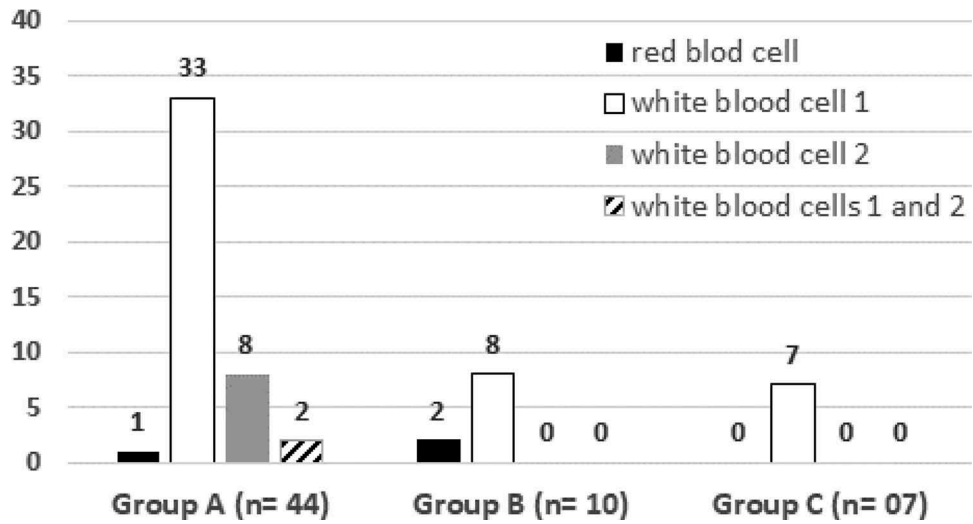

Figure 13. Results from question 1, for the association between content and representation. Y-axis indicates number of answers.

Survey results

The 'Giant Artery' was approved by 99% of the respondents, who gave answers that they very much liked (☺) the visit in the general opinion question 1. Only 1 visitor of 61 did not like the installation. The other questions further explored public opinion, revealing that the visit to the model was pleasant and meaningful, favouring the communication of knowledge in an interactive way and strengthening the relationships between man, art and science. This reinforced our conviction that both have always been necessary for the communication among individuals. Figure 13 and the word cloud (Supplementary materials) show the results of questions 1 and 3, respectively.

Figure 13 shows that 95% of the respondents correctly answered the second multi-choice question, concerning white blood cell 1 (open/cross-sectioned), white blood cell 2 (closed/three-dimensional) or both options. Only three visitors responded incorrectly, flagging the red blood cell image. The association between conceptual content and representation was particularly perceived in the largest Group (A): the two types of white blood cells (second and fourth options in the second multiple choice question of the questionnaire, as seen in Supplementary materials) were marked as correct. However, the predominance of 33 marks in white blood cell 1 in favour of Group A, as well as all the associations made by Groups B and C, suggest that visual association was stronger and/or easier to perform. We obtained no answers marking the glucose molecule. Two students from Group A pointed out the two images of white blood cells, possibly indicating that, in addition to the visual similarity, these visitors considered the content of this component relevant in the two formats in which it was represented. Eight visitors from Group A indicated only white blood cell 2 that represented the cell shape.

Of the respondents who correctly marked the white blood cells, 24% preferred the 'closed' white blood cell image, suggesting the association between the model and the theoretical content, different from the visual relationship made through similarities and characteristics of most respondents. This preference indicates the understanding by these visitors that the real leucocyte is 'closed' in three-dimensions.

To determine whether there was communication between visitors and the concepts present in the art installation, we considered 52 answers (85%) to the first open question, that contained some 'concrete learning report' and that addressed the main concepts presented in the model and/or exposed by the mediator during the visit (Table 1, Supplementary materials). Only 9 of 61 responses were considered negative because they did not contain learning reports or were confusing, disconnected or generic.

Table 1 is organised by conceptual categories and frequency of occurrence. Thus, we note that more than one quarter (16 reports, 26%) of the answers focused on the 'functioning of things,' followed by reports of arterial obstruction (9 reports), immunity (7 reports), coagulation (6 reports), and blood vessels (6 reports). Four other categories were cited in the minority (1 to 3 reports each), including the sound of blood flow, food, platelets and enzymes, themes proposed in the mediation. These results suggest that the experience of learning during the art-installation visit may vary according to the subject discussed by the mediator. Sickle cell anaemia, blood sugar control, and red blood cells were concepts learned by 57% of the participants in this group and were present in 28% of learning reports.

In Group C, 60% of the participants learned concepts different from the *Saturday of Science* main subject, which was 'Sounds of the Heart,' a concept acquired by 30% of these participants. The creation of this art installation was carefully designed for translation of complex phenomena and natural features into artistic conceptual signs to facilitate understanding, resulting in matching of meaning and content. During mediation within the Giant Artery, the visitor assumed an active role to produce knowledge by connecting pre-established concepts to the model's visual and tactile objects.

For the analysis of the third item of the questionnaire, we generated a 'Word Cloud' with the words registered by the visitors (Supplementary materials).

Table 1. Examples of concrete learning reports by categorised theme.

Physiology (the functioning of things) and blood cells (16/61 = 26.2%)
P9–12 y – 'I could better understand the functioning of things within an artery.'
P50–18 y – 'That all these cells exist in the blood and the function and importance of each one.'
P51–19 y – 'I learned that when we have sickle anemia the red blood cell changes its shape and stops carrying oxygen.'
P44–13 y – 'The blood has red blood cells, leucocytes.'
P55–18 y – 'About red cells being anucleate cells.'
About fat and arterial obstruction (9/61 = 14.7%)
P33–13 y – 'How is a vein clogged with fat.' (3 persons)
P19–13 y – 'That the pressure increases when there is more fat on artery walls.'
P60–52 y – 'That it can accumulate saturated fat ant it can no longer be removed.'
Vaccines, antibodies, immunity (7/61 = 11.4%)
P3–10 y – 'I learned that you have a white blood cell, which defends people from disease.'
P43–13 y – 'The white blood cell is for the immune system. I learned a lot of things.'
P23–13 y – 'The vaccine produces antibody.'
P26–13 y – 'The vaccine stimulates antibodies.'
P31–13 y – 'That has several cool things, that protein and antibodies exist.'
Fibrin and coagulation (6/61 = 9.8%)
P15–13 y – 'I learned about the fibrin net.' (five answers)
About blood vessels (6/61 = 9.8%)
P6–12 y – 'The difference between artery and vein, how platelets form, etc.'
P37–13 y – 'I had a sense of what it's like an artery inside.'
P57–43 y – 'I learned how to assemble a giant artery – an idea to reproduce in high school.'
About the sound of blood flow (3/61 = 4.9%)
P2–10 y – 'That when there is too much bad fat in the blood wall, when the liquid passes it, a noise occurs similar to when soda passes through a straw.'
P58–46 y – 'About the sound the artery makes when it is fat.'
P48–15 y – 'Fat plates block passage and modify the sound.'
Food (3/61 = 4.9%)
P1–9 y – 'That food is very important to our human body.'
P30–13 y – 'That the piece of meat we eat become protein, has to go through digestion.'
P54–25 y – 'The importance of controlling sugar consumption.'
Platelets (3/61 = 4.9%)
P5–12 y – 'I learned that when there is a skin lesion the platelets change shape'
P7–12 y – 'About the performance of platelets when they are activated and change shape.'
P12–12 y – 'About the platelets and a clogged vein with fat.'
Enzymes (1/61 = 1.6%)
P4–12 y – 'There are several types of enzymes.'
Disconnected (5/61 = 8%) and generic (4/61 = 6.5%) sentences
P10–12 – 'I learned how artery cells.'; P17–13 – 'I didn't know I had no protein.' P59–52 – 'Traveling in the blood.'; P49–17 – 'They are the most important.'

* Not all answers but only examples of phrases recorded in the questionnaires.

The results from the third open question represented in (Table 2, Supplementary materials) revealed that there were no numerical differences between the three groups of visitors; therefore, we grouped the responses. There were 57 answers to this question. We made two categorisations, the first by the type of content highlighted in the answer, and the second by the adequacy of the answer, grouping citations with correct components and functions (n = 47, 82.5%), citing only the molecular or cellular components, but without their functions (n = 6, 10%), with misconception (n = 3, 5.2%) and with confused or disconnected citations (n = 1, 1.7%). Table 2 (Supplementary materials) shows examples of citations. Visitors remembered cells (platelets, white and red blood cells) as well as molecules (fat, protein and antibodies). The high frequency (82.5%) of correct answers points to the adequate readability of the model regarding the concepts that are sought to work with the visitation in the installation, strengthening its validation as an educational instrument. The number of mistaken or confusing answers was below 10% (4 out 57, equivalent to 7%), thereby validating the model. We

Table 2.

	Examples (P = participant, age in years)
Citation category (n = number of citations)	Correct Citations
White blood cells/leucocytes (n = 19)	P12–12 y – 'White blood cell – Defense of our body against invading agents'
	P15–13 y – 'White blood cell. Helps in defense'
	P16–13 y – 'From the white blood cell, that defends the system'
	P6–12 y – 'Leucocytes. They defend the body'
	P19–13 y – 'White blood cells – defend the body'
	P22–13 y – 'White blood cell – defense of the system'
	P11–12 y – 'White blood cell helps against pathogens'
	P58–46 y – 'White blood cell, that helps fight viruses'
	P42–13 y – 'White blood cells and immunization help'
	P7–12 y – 'Leucocyte – Responsible for body immunity'
	P5–12 y – 'White blood cells – Produces antibodies to defend the body'
Red blood cell (n = 15)	P9–12 y – 'Red blood cells – carry oxygen.'
	P25–13 y – 'Red blood cells, carries respiratory gases.'
	P13–13 y – 'Sickle red blood cells may clog the passageway.'
	P43–13 y – 'Half–moon red blood cells that get in the way.'
	P59–52 y – 'Red blood cells – blood color.'
	P61–71 y – 'Red blood cells. Important for the functioning of our organism.'
Platelets (n = 3)	P3–10 y – 'Platelets: form the bruise and a clot.'
	P39–13 y – 'Platelets. Stop hemorrhage, form bark.'
Fat (n = 9)	P4–12 y – 'Fat'
	P50–18 y – 'Cholesterol build up in artery wall'
	P53–24 y – 'Walls and fat that can stick together'
	P60–52 y – 'At accumulation of saturated fat in the walls of the artery'
	P34–13 y – 'Bad fat clogging the artery'
	P54–25 y – "With excess fat consumption (especially trans–fat)
Antibodies (n = 5)	P29–13 y – 'Antibodies – from immunity.'
	P33–13 y – 'Antibodies, protect the body against invading agents.'
	P21–13 y – 'The antibodies coming out of the white blood cell. Helping in fighting … '
Others (n = 5)	P31–13 y – 'Protein, it's broken.'
	P38–13 y – 'Glucose molecules give energy to body.'
	P41–13 y – 'I learned about the cells.'
	P45–13 y – 'Calcium, strengthens the bones.'
	P51–19 y – 'Because there was a cut in the artery and it formed a clot to close the opening.'
Citations including more than one component(n = 3)	P2–10 y – 'Red blood cells: take O_2 and nutrients to cells. Leucocytes: Fight all virus is that enter the body and blood.'
	P14–13 y – 'White blood cells, antibodies and fat.'
	P56–40 y – 'Platelet – White blood cell. Responsible for the defense of our body.'
Confused/wrong citations (n = 4)	P40–13 y – 'White blood cell. They defend the cell.'
	P44–13 y – 'Leucocytes, defend the cell.'
	P55–18 y – 'With the accumulation of fat hematophagous roaring in the artery wall.'
	P49–17 y – 'Saturated fats coming in from ash fabrics'

* Not all answers provided but only examples of phrases recorded in questionnaires.

grouped wrong two responses that indicated that 'white blood cells defend cells,' while most correct answers indicated the defence of body," 'system' and 'organism.' These answers helped to improve mediation, suggesting that this point needs to be reinforced.

Discussion

The creation of the 'Giant Artery' installation was carefully planned to translate complex natural phenomena into artistic signs that would facilitate understanding, resulting from the amalgam of meaning and content. Bridging the conceptions of art and science, it was possible to add to the scientific environment artistic concepts for a meaningful communication of contents.

Language development in humans entails arises from need for interpersonal communication. The more well-known a particular language is among individuals, the more efficient communication in that language will be. Peruzzo and Krohling. (2004), in his book 'Communication in Popular Movements', says that '... *some experiences of popular involvement in communication prove that men and women have the potential to be subjects of history. Being subject and not mere object is the essence of the human condition*' (Peruzzo and Krohling. 2004, 23, free translation from Portuguese into English by the authors). For knowledge construction, when a person is intended to be the subject who will practice the action, an important characteristic is understanding a particular phenomenon or concept. The abundance of concepts within a museum context often hampers the assimilation of concepts, because the interpretation of the individual is unpredictable, and because it is personal and inaccessible. Art assumes the role of access to the interpretation of others; however, it is necessary to identify the response brought by the individual.

In dealing with so many aspects, in the dimension of education, an interactive educational model was constructed and thought to be a learning instrument. When the visitor enters the art-installation model and believes for a moment to be within an 'Artery,' they can associate concepts already learned, whether specifically or not. This builds an imaginary reference framework, relating through comparisons to the features presented in the model and to the functions occurring in their own circulatory system. However, in an analogy to what happens during the dramatic experience in theatres, the model does not work alone. In the theatre, the show conveys the central message only if the audience identifies with the context. In a science museum, it is not enough that there is only identification, there must also be insight and sparks. The visitor needs to visualise the actual object portrayed by the model, that must have parameters to make possible such associations.

The use of analogies in the teaching-learning process of natural sciences has been studied by researchers such as Duit (1991), Sutton (1996), Venville and Treagust (1997), among others (Delizoicov, Carneiro, and Delizoicov 2004). Root-Bernstein and Root-Bernstein (2001) defined models as objects specially employed to display characteristics of elements that cannot be observed directly. To communicate certain content, the use of analogies and similarities stimulates the visitor's imagination to provide learning.

> Reproducing an atom or a cell on a scale millions of times larger than its actual size can integrate information from hundreds or thousands of experiments and thereby represent sophisticated theoretical concepts. Even a human head or heart can be enlarged and occupy a museum room such that people can experience the sensation of exploring the inside of their own mouths, their faces or ear lobes, or accompanying the trajectory of blood flow. The extraordinary size of the model allows people to play the role of something much smaller-perhaps a red blood cell, a microbe, a molecule, or the air (Root-Bernstein and Root-Bernstein 2001, free translation of Portuguese into English).

An investigation showed that the 'heart-bomb' analogy, often used in the teaching of human circulation, introduces difficulties to the teaching-learning process of this topic. The teachers that were interviewed stated that they were not able to teach about blood with this 'interpretive model,' nor about the historical aspects that guided this analogy (Delizoicov, Carneiro, and Delizoicov 2004). The 'Giant Artery' asks the visitor to draw analogies to situations they may have experienced to learn such concept, including the representation of a clot in the wall of the model. There, it is explained what happens in the blood vessels after a cut, rupture or damage, until the formation of the bruise on the skin.

The project ‘Science – Blood and Citizenship’ accomplished in the ECV allowed the creation of several workshops on this subject, acting as a tool to foment discussion about various aspects of blood physiology, highlighting the importance of donation and undoing existing myths and prejudices. The ‘Blood Scrubbing’ workshop, for example, allows the visitor to learn more about blood, complementing the visit in the art installation with the actual observation of stained rabbit blood cells using a microscope, allowing the clarification of possible misconceptions absorbed from the model. The present reported experience favours the development of more art installations that link science and art concepts, aiming to increase public awareness of biological concepts.

The ‘Giant Artery’ broke curriculum paradigms by joining two major and important areas of knowledge, art and science, in order to communicate publicly useful content and of great symbolic and affective meaning to the general public. Approval on the part of visitors communicates concepts about the circulatory system, including the representation of characteristics and functions of its components in an imaginary way. The Cienciarte approach used in the construction of the Giant Artery was important for the development of the playfulness and curiosity about the scientific knowledge employed. It can be used to promote cognitive learning in this scenario, allowing learning of scientific content in an associative way, causing the proactive interaction of visitors with physical and sensory resources. Ionising the construction of new knowledge, arousing positive and pleasant sensations by enabling participant contact with knowledge.

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References

Araújo-Jorge, T. C., T. S. Cardona, C. L. S. Mendes, A. Henriques-Pons, R. M. S. Meirelles, C. M. L. M. Coutinho, L. E. V. Aguiar, M. N. L. Meirelles, S. L. de Castro, H. S. Barbosa, and M. R.M.P. Luz. 2004. “Microscopy Images as Interactive Tools in Cell Modeling and Cell Biology Education.” *Cell Biology Education* 3: 99–110.

Ardoino, J. 1980. *Perspectiva politica de la educacion*. [Political perspective of education]. Madrid: Narcea.

Bardin, L. Análise de Conteúdo. Lisboa, Portugal; Edições 70, LDA, 2009

Cavalcanti, C. C. B., and P. M. Persechini 2011. “Science Museums and the Popularization of Science in Brazil”. *Field Actions Science Reports* [Online], Special Issue 3. http://journals.openedition.org/factsreports/1063

Constantin, A. C. C. 2001. “Museus interativos de ciências: espaços complementares de educação.” [Hands on science museums: complementary spaces of education]. *Interciencia, Portugal* 26 (5): 195–200.
de Paula, L. M., A. S. Ruiz, G. R. Pereira, V. A. Andrade, R. Coutinho-Silva, and E. Kurtenbach. 2015. “Um sábado de grandes descobertas: Um olhar acerca dos sábados da Ciência do Espaço Ciência Viva no Rio de Janeiro.” [A Saturday of Great Discoveries: A Look at Saturdays of Science at Espaço Ciência Viva in Rio de Janeiro]. *Latin American Journal of Science Education* 1: 22011-1-22011-14.
de Paula, L. M., G. R. Pereira, and R. Coutinho-Silva. 2019. “A função social dos museus e centros de ciências: integração com escolas e secretarias de educação.” [The social function of museums and science centers: integration with schools and education departments]. *Ciência e Cultura* 71: 4–5. doi:10.21800/2317-66602019000200002.
Delizoicov, C. N., M. H. S. Carneiro, and D. Delizoicov. 2004. “O movimento do sangue no corpo humano: do contexto da produção do conhecimento para o do seu ensino.” [The movement of blood in the human body: from the context of knowledge production to that of its teaching]. *Ciência & Educação* 10 (3): 443–460. doi:10.1590/S1516-73132004000300009.
Duit, R. 1991. “On the Role of Analogies and Metaphors in Learning Science.” *Science Education* 75 (6): 649–672. doi:10.1002/(ISSN)1098-237X.
Field, H., and P. Powell. 2001. “Public Understanding of Science versus Public Understanding of Research.” *Public Understanding of Science* 10 (p): 421–426. doi:10.1088/0963-6625/10/4/305.
Gomes, L. S. C., L. S. Cardoso, and E. Kurtenbach. 2018. “Participação de mediadores na elaboração de cartilha experimental para uso em ensino não formal e formal.” [Participation of mediators in the elaboration of an experimental booklet for use in non-formal and formal education]. In *Desafios do Ensino de Ciências na Atualidade*, edited by R. Coutinho-Silva, G. R. Pereira, and L. M. D. P. Lunha. Vol. 1, 07–23. 1ed.Rio de Janeiro: Espaço Ciência Viva.
Kurtenbach, E. Persechini and R. Coutinho-Silva R. 2004. Espaço Ciência Viva: ciência e arte desde 1982 [Life Science Space: science and art since 1982]. In Ciência e Arte: Encontros e Sintonias [Science and Art: Meetings and Tuning], edited by Tania C. de Araújo-Jorge, 146–153. 1ª edição. Rio de Janeiro: Editora Senac-Rio
Leenaars, F., W. Van Joolingen, and L. L. Bollen. 2013. “Using Self-made Drawings to Support Modelling in Science Education.” *British Journal of Educational Technology* 1 (44): 82–94. doi:10.1111/j.1467-8535.2011.01272.x.
Marandino, M. 2008. *Educação em museus: a mediação em foco*. Universidade de São Paulo, São Paulo: Geenf.
Ostrower, F. 2010. *Criatividade e processos de criação*. [Creativity and creation processes]. 25ª ed. Rio de Janeiro: Editor Vozes.
Pereira, G. R., M. V. Chinelli, and R. Coutinho-Silva. 2008. “Inserção dos Centros e Museus de Ciências na educação: Estudo de caso do impacto de uma atividade museal itinerante.” [Insertion of Science Centers and Museums in education: Case study of the impact of a traveling museum activity]. *Revista Ciências & Cognição* 13(3): 100–119.
Peruzzo, C., and M. Krohling. 2004. *Comunicação nos movimentos populares: a participação na construção da cidadania*. [Communication in popular movements: participation in the construction of citizenship]. 3ª ed. Rio de Janeiro: Vozes.
Root-Bernstein, R., and M. Root-Bernstein. 2001. *Centelhas de Gênios: Como pensam as pessoas mais criativas do mundo*. [Sparks of Genius: How the Most Creative People in the World Think]. São Paulo: Nobel.
Silva, H. C. 2006. “O que é divulgação científica?” [What is scientific dissemination?]. *Ciência & Ensino* 1(1): 53–59.
Souza, K.R., and M. T.M. Kerbauy. 2017. “Abordagem Quanti-qualitativa: Superação Da Dicotomia Quantitativa-qualitativa Na Pesquisa Em Educação.” *Educação E Filosofia* 31 (6): 21-44. doi: 10.14393/REVEDFIL.issn.0102-6801.v31n61a2017-p21a44.
Sutton, C. 1996. “Beliefs about Science and Beliefs about Language.” *International Journal of Science Education* 18 (1): 1–18. doi:10.1080/0950069960180101.
Urssi, N.J. 2006. *A Linguagem Cenográfica*. [The Scenographic Language]. Ed. Universidade de São Paulo, 122p. Available at http://www3.eca.usp.br/sites/default/files/form/ata/pos/ppgac/A%20linguagem%20cenografica.pdf.
Valente, M. E., S. Cazelli, and F. Alves. 2005. “Museus, ciência e educação: novos desafios.” [Museums, science and education: new challenges]. *Revista História, Ciência, Saúde-Manguinhos* 12 (supl): 183–203. doi:10.1590/S0104-59702005000400010.
Venville, J. C., and D. F. Treagust. 1997. “Analogies in Biology Education: A Contentious Issue.” *The American Biology Teacher* 59 (05): 282-287.