

Information and Communication Technologies (ICT) in educational research in science museums in Brazil

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ABSTRACT

The last forty years have seen significant growth in the area of research in science education in Brazil. Faced with the volume of academic output, studies that present a descriptive character are necessary. However, “states of knowledge surveys” are still rarely found in the field of science education. In this context, the objective of the research presented in this article was to identify and describe the main characteristics and tendencies of Brazilian research on education in science museums, considering dissertations and thesis that address the use of information and communication technologies (ICT) in non-formal education spaces, as research problems. A mixed methods approach of qualitative and quantitative research was used, and a documentary analysis was carried out. Thirteen studies that focused on ICT in science museums were mapped, drawn from 11 dissertations and 2 theses that were produced in Brazil over a period of 25 years from 1991-2015. This is a theme that is not well explored nationally. In the paper we seek to contribute to the discussion with a view to listing possibilities for the development of new practices and investigations.

Keywords: *online learning; social appropriation of technology; virtual communities*

INTRODUCTION

The social appropriation of science and technology (S&T) has fundamental relevance to the challenges posed by globalization, as well as scientific and technological advances and information and communication technologies (ICT). ICT can be understood as a set of technological resources that can provide the interaction and automation of different media forms applied to various fields of knowledge, such as commercial, economic and educational areas. When it comes to education, ICT can lead to improved learning resources, articulating information through processes of transmission (what is proposed) and communication (as it is proposed) of certain educational objects. It can also help with the integration of different resources, including hardware and the development of software that allows the operationalization of communication.

Faced with the challenges posed by ICT, educational processes have been developed using multiple and heterogeneous channels, among which are distinguished science museums - privileged spaces for the development of practices in the field of non-formal education - either physically or virtually, with the use of the Internet. Its main purpose in relationship with society concerns the possibility of participation by scholars and the population in general.

Papers in the field of education have discussed the importance and the necessity of policies and strategies that effectively assist with the understanding of scientific knowledge through out-of-school experiences, such as those occurring in science museums (Falk and Dierking, 2016; Marandino, 2003). Regarding research in science education, Marandino (2003) states that it must promote the articulation of specific knowledge with pedagogical ones, seeking to incorporate in its programme the questions that are now posed to both, for the wider educational field and for science itself. From this perspective appears the theme of non-formal education and scientific dissemination. However, little is known about the various aspects of this production, about the scope of the studies carried out, about the main research focus, the lines of research, the paths

covered, the gaps that exist, the production centers and the contributions of these investigations to the educational system as a whole.

Nascimento and Ventura (2001) point out that one of the great transformations, begun at the end of the 20th century and underway in the area of museum studies, is the adoption of new communication technologies. In this regard, Eler (2008) notes that use of the Internet stands out. The increase in use of the Internet, especially Web 2.0 and the interactivity provided by it, increased the dissemination of scientific information, a fact experienced by science museums around the world.

ICT is a reality in the context of museums and represents the possibility of expanding the areas of activity of these institutions, providing access at any time to information and its collections, as well as allowing interaction between the public and the institution through blogs, simulations, activities, and chat, among others. Cooper (2006) argues that, contrary to the statements made by many museologists during the 1990s, the advent of information and communication technologies, re-dimension the museum experience, since they enable personal involvement and the participation of the community. In this way, the technologies can increase the visitors' experiences regarding the museums on the web, but they are not characterized as substitutes for the visits to the physical museum. They allow access to visitors in geographic area that are prevented from carrying out in-person visits.

According to Kyprianos et al. (2019, p. 1), "museums have become mediated entities, which rely on different types of media to create and distribute content to visitors and other cultural consumers". These scientific-cultural spaces are engaged in gathering, processing and distributing information and to do this, they take into account ICTs that are recognized as sophisticated disseminators of cultural content.

Given the above considerations, the research presented in this article maps the dissertations and theses produced in Brazil over the 25 year period 1991-2015, that approach ICT as resources of support to the scientific education developed in science museums.

THEORETICAL CONTRIBUTIONS

ICT in the context of science museums at the international level: a brief review

The important role of ICT for communication interaction and for collaborative learning in the educational sector has been prominent in the literature. Agbo et al. (2020) present a positive relationship between social media usage for computing education and perceived learning outcomes. Eslamian et al., (2019) discuss factors that impact on students' productivity and ability to use ICT resources in an educational environment. These factors include: (i) digital technology acceptance, (ii) attitudes toward technology, (iii) cloud-based services and (iv) capacity of IT-based systems which have a significant influence on students' productivity. These factors reinforce the potential for including ICT resources in science museums, whether physical or virtual, particularly when we consider that the priority audience of these institutions is still the school (Falk and Dierking, 2016).

In this context, the traditional museums are educational and tourism spaces which by the inclusion of new pedagogical strategies, allow greater interaction between the cultures offered by these institutions with the citizens (Sánchez et al., 2018). There is a growing trend, in these spaces, to integrate holographic technology, augmented reality and human-robot interaction, which make museums more interactive spaces in a scientific dissemination process. Thanks to the increasing use and advancement of ICTs, the implementation of these technologies within museums has been

more frequent and has favored or increased the number of visitors to these cultural institutions. In this way, Ibero-American Virtual Museums have been characterized as contexts for the teaching and learning of science (Sánchez et al., 2018; ABCMC, 2015).

The mission of science museums is to contribute to the incorporation of science in the general culture of society. The collaboration between science museums and schools expand opportunities for teachers and students to maintain contact with the sciences. Since the advent of ICTs, museums have sought to incorporate these resources into their programme, resulting in the existence of virtual museums that offer meaningful educational experiences. Rasino et al., (2020) conducted content analysis of 28 museums located in Spain across three areas: ICT, Didactics and Science. The authors concluded that most of the virtual museums show progress in the 'ICT' area, but interactivity needs to be improved. In regard to the 'Didactics' dimension, the authors noted that virtual museums must include resources that deal not only with conceptual, but also with procedural and attitudinal content. In relation to the "Science" area, these spaces must provide a vision of applied science, which takes the historicity of knowledge into consideration. The authors note that:

"It is recommended that teachers choose the learning scenarios which have the best characteristics concerning the studied dimensions, that they exploit the social media of the museums and that they develop specific activities which are meaningful to the classroom practices around a specific virtual museum" (Rasino et al., 2020, p. 1).

In the context of the United States, Bellinger (2018), investigated the ways that museums might incorporate technology, in addition to current artefacts employed in these spaces, considering visitors who might come to museums alone, in a wider group, or as part of a school group. In the conclusion to the study, the author reinforced the view that ICT shifts the landscape of the cultural heritage sector, but does not destroy it. For her, museums would adapt to the new scenario and find ways to develop their activities. In addition, ICTs "can be used to foster engagement and social-media can be used for engagement, promotion, and supporting the social aspects of museum visits" (p. 66). Finally, she states that the research has shown that technology can provide new tools for old tasks and we have to take care to note this (Bellinger, 2018).

The development of personal computers makes possible the reproduction of complex content, and with the availability of Internet services, the possibility for virtual presentation of collections of cultural artefacts and the so-called "virtual museums". Chiuppesi (2016), after a review of some definitions of "virtual museum", in Italy, proposed a typification of this phenomenon, focusing on the potential impact of virtual museums on social inclusion. The author warned that, in addition to the obstacles in general associated with museological institutions for inclusive enjoyment, which, in turn, promotes the inclusion of society in general, virtual museums run the risk of introducing obstacles. These are related to the fact that Internet services are still not universal, as well as the specific characteristics of the platforms used for the collection's virtualization. Virtual museums are likely to become an additional element of cultural diffusion, but barriers of a technical and social nature may continue to reproduce inequalities in access to this knowledge.

ICT in the context of science museums in Brazil

As a more recent research perspective in the field of education in science museums, the question of ICT is posed, including virtual museums and development of resources to support education and scientific dissemination in these spaces. It is an aspect that is still not adequately researched and discussed in the Brazilian scenario, which considers the science museums as media. However, their characteristics distinguish them from other communication vehicles considering the possibilities of conferring interactivity, in their physical and affective components, in an interactionist way, be it hands-on, minds-on, hearts-on, social-on or explainers-on (Pavão & Leitão, 2007), in order to promote a message.

At present, the need for the interaction of individuals with new technologies is present in our daily life with the use of mobile phones, issuing bank statements, typing on computers and conducting school research, among other necessities. According to Lino (2010), the population that does not dominate the use of ICT would like to know it and be able to acquire these tools for use. However, in Brazil a great barrier to the approach to ICT is through issues ranging from the acquisition of the tools, and a lack of connectivity in some regions of the country to the domain for use of the tools, a fact that has direct repercussions on science education.

Lino (2010) also reports the increase in the number of public places that provide access to digital technologies for the population, although in a very small number. Limited access is available due to the extension of the national territory and the socioeconomic diversity existing between the regions of Brazil. Among the public places that offer access to ICTs, science museums come to the fore, as they also become spaces for the population to have contact with science through the technologies.

Today, we cannot think of a meeting between science and society, without taking into account the ICTs, which are present in our everyday life and which allow interaction between individuals and society. With the insertion of the Internet in everyday life we observe how information arrives more quickly, but the great challenge is to transform the information received into knowledge. If we consider the case of exhibitions in science museums, we can say that the information contained therein can provoke the individual in such a way that he or she searches for other related data. In this confrontation with several sources of information, it is possible for the visitor to construct knowledge about the subject as a result of the search carried out after the visit. This process gives the visitor a restlessness that results in an approximation with the themes related to science.

To Bizerra (2009), even in the face of the expansion of interaction possibilities offered by ICT in science museums, other research that sought to understand the role of this tool in the learning process of the visitors was not forthcoming. According to the author (p. 56),

"there are few researches on the use of recent technological systems in exhibitions, collections and information management or communication between researchers in the field (as in digital networks of research groups)".

The author noted that other areas not related to learning in science museums, such as investigations that deal with the use of these tools in conservation of collections, are more frequent. Bizerra (2009, p. 56) further noted that "it is believed that this is a theme with a strong tendency to expand among museums and promises to constitute itself as an important research field". In view of the importance that this thematic has assumed in the contemporary society, it is noteworthy that the newspaper "Museum Management and Curatorship" included a section about digital heritage, in its editorial in 2008.

About the insertion of ICT resources in science museums

In addition, the inclusion of the theme in the agenda of science museums is necessary, given the amount of electronic information available, in addition to the increasing number of computer users and the Internet, mainly due to the reduction of the costs of computer equipment and the expansion of networks. This situation accentuates the need to use query tools with quick access that are adapted to the users' characteristics.

According to Gouveia (2007), the interface of museums in general with computer science began in the 1960s and started from the need to organize collections and exchange information between institutions. This interface evolved over the next two decades and in parallel with the advancement

of computers. In the 1990s, with the advent of the Internet and the expansion of access to the network and computers, science and technology museums, such as the Boston Museum of Science, began a process of presenting their exhibitions, contemplating technological advances in the network as a mark of its pioneering spirit. Today, this is a growing reality throughout the world and has been gaining more and more space in Brazilian science museums.

Besser (1997) argued that ICT has changed the way museums perform their functions, as well as their perception by the public. According to the author, museums would follow the steps of libraries, cultural institutions that have always been about a decade ahead in the process of incorporating technologies. This view is in keeping with Tagueña's (2005) statement, for whom museums are the second educational institution to which students turn for the development of their school research, Libraries are in the first place. Gouveia (2007, p. 22) states:

"In the last ten years, new models have been developed by museums and science centers to popularize science from the Internet, both for its use and as an electronic leaflet in order to publicize the institution, as a virtual visit to existing spaces or even to an imaginary exhibition".

In 1999, Díaz and Egido pointed out that museums in general, and science and technology in particular, were beginning a process of mobilization for the Internet and that a large number already had websites, some containing more information than others. Bowen (1999) broadened the discussion by claiming that there is a need to observe what museum site visitors wanted. According to Bowen, 74% expected to find virtual exhibitions and around 50% expected to find images that could be downloaded on the web. Even with this information, Gouveia (2007) points out that virtual exhibitions still do not integrate a significant part of the sites and that the availability of quality images on the web is still a question that raises great debate. Broadly speaking, according to Gouveia, museum sites translate a vision of the Internet space as a diffusion environment. This perspective is also present in certain works that integrate the corpus of the present investigation.

It becomes evident that there is need for a closer look at the relationships existing in the triad of the school-science museum-ICT, in particular on what has been researched and published about the subject, and the possibilities of working with the education sector in face of the new demands placed on the science museum environment. A new scenario emerges in which the science museum appropriates ICTs and goes to the visitor, in a perspective of mutation and transformation of science education.

METHODOLOGICAL APPROACH

In view of the discussion above, the Brazilian Digital Library of Theses and Dissertations (BDTD), linked to the Brazilian Institute of Information in Science and Technology (IBICT), an organ of the Ministry of Science and Technology, was consulted using the term "science museum" as a descriptor. Considering that this term may limit the search for dissertations and theses, we consider the definition presented by the Brazilian Association of Museums and Science Centers (ABCMC). ABCMC follows the guidelines of the International Council of Museums (ICOM) approaches as synonyms the expressions "science museums" and "science centers" as any institution involved in scientific dissemination, since the boundaries between two spaces are not clearly delineated. Thus the descriptor "science museum", although broad, does not consider the diversity of spaces characterized. Therefore, it was necessary to include other descriptors for the search carried out in the BDTD, including the expressions "zoo", "botanical garden", "aquarium" and "planetarium", "zoobotanical" and observatory", according to the delimitation present in the Catalog of ABCMC (ABCMC, 2015).

This is the concept used throughout this paper. After reading the abstracts of the dissertations and theses obtained through the cross match of the two search engines (author/dissertation or theses), 542 outputs were mapped, however, some of them indicated overlapping of output. In this way, after a new screening, we found 195 outputs. The difference is also linked to theses and dissertations that presented the descriptors "museum and education" as a general theme, not contextualized for the scientific subject studied. Of this total, 13 refer to ICT and education in science museums, with 11 dissertations and 2 theses produced in Brazil in the last 25 years (1991-2015).

The present research is characterized, therefore, as documentary, historical-bibliographical (Fiorentini and Lorenzato, 2006). According to these authors, this modality "[...] is preferably done on written documentation" (p. 102), and information collection is carried out from the readings file. As the main empirical material, we opted to work with *stricto sensu* productions, since most of the research carried out in Brazilian higher education institutions is linked to master's and doctoral courses.

RESULTS AND DISCUSSION

Next, we will present the results of the analysis performed. Table 1 presents information about the mapped dissertations and thesis.

Table 1: Number of dissertations and theses

Nº	Author	Year	Post-Graduation Programme	Degree	Title
1	Maruyama, J.A.	2013	Chemistry/Federal University of São Carlos	M	The use of information and communication technologies in the school visits for the Araraquara Science Center
2	Romanzini, J.	2012	Science Teaching and Mathematics Education/State University of Londrina	M	Construction of a summit session for the Physics teaching in a planetarium
3	Carmona, S. P. K.	2011	Communication and Semiotics/Pontifical Catholic University of São Paulo	M	The Game Museum as a gaming experience
4	Lino, L. da S.	2010	Educational Technology for Health/Federal University of Rio de Janeiro	M	Digital inclusion: the view of museums and science centers
5	Oliveira, C. E. Q. V. de.	2010	Science Teaching/University of Brasilia	M	Multimedia Astronomy: the construction of the virtual exhibition 'Astronomy - an unforgettable journey'

6	Palma, A. M. M.	2009	Teaching in Biosciences and Health/Oswaldo Cruz Foundation (Fiocruz)	M	Who chat? An exploratory survey of the virtual museum "InVivo"
7	Eler, D.	2008	Technological Education/ Federal Center for Technological Education	M	Internet and STS Studies (Science, Technology and Society): an opportunity for the implementation of forum-museums
8	Gouveia, F. C.	2007	Biological Chemistry/Federal University of Rio de Janeiro	D	Webometrics Studies of Associations of Museums and Science Centers
9	Bertoletti, A. C.	2006	Informatics in Education/Federal University of Rio Grande do Sul	D	A virtual community support environment based on learning object repositories to support informal learning in museums
10	Rela, C. M. S.	2002	Communication/Mackenzie Presbyterian University	M	The internet in high school Physics
11	Brito, C. C.	1999	Arts/University of Brasilia	M	Space-Inter-Space
12	Moraes, M. C.	1999	Computing/ Pontifical Catholic University of São Paulo	M	An architecture of improvisational agents to support the visitation of museums based on computers
13	Bertoletti, A. C.	1997	Computer Science/ Federal University of Rio Grande do Sul	M	Sagres: a system with adaptive presentation of information and support for group interaction

*M: Masters; D: Doctoral

In regard to the investigations presented in Table 1, 6 were developed in postgraduate programmes in the area of Teaching, 2 in Computer Science (these, in addition, refer to the development of software as resources to support museum education), 2 in Communication, 2 in Chemistry and 1 in Arts. Based on the work described in the table above, we noted the following:

-) Research 1 deals with the use of ICT in the Technological and Investigative Gymkhana of Chemistry, promoted by the Araraquara Science Center, linked to the São Paulo State University (Unesp). The research investigated the use of such resources in the activity, as well as the participants' understandings on such use and the contributions to the teaching of Chemistry. As the author affirms, students of the public and private schools carried out the construction of the empirical material by means of a questionnaire at the end of the

- visits. The computer is characterized as a resource used by the participants during the gymkhana, to solve the presented situation. In addition, participants also used the Internet as a mediator of actions. Among the results, the author mentions that the relation of students with the use of technological resources changes their relation with the chemical content - the participants show greater interest in the use of equipment (cell phones and computers), which dynamizes the search for information. In the view of visitors, this facilitates the research and makes the research more motivating. The potential of ICT was explored especially as a support to visitors in solving a Chemistry problem presented, motivating the use of the Internet as a resource in museums.
-) Research 2 is based on the educational possibilities of planetariums in order to contemplate concepts of the sciences that include fields such as Biology, Physics, Mathematics and Chemistry. To do so, the author investigates the construction of a summit session to work topics related to the operation of telescopes. In the definitions, he mentions that, having been considered as great attractions of the planetariums, the summit sessions are characterized as virtual presentations, in digital format, that simulate immersions in the Sky. The elaboration of the session was applied at Londrina's Planetarium/State of Paraná. High School students were evaluated with pre-test and post-test. The results most clearly suggest the influence of the activity on the writing of students who had never had contact with the subject. According to the researchers, students also highlighted aspects concerning pedagogical, cognitive and sociocultural values as a means to approach the subjects studied in the school.
 -) Research 3 deals with the construction of a game museum in order to allow a gamified experience to the visitors, that is, the application of the dynamics presented in games in daily situations. The justification for the study considers that games are present in the lives of everyone, in addition to the young audience, which highlights their importance for future generations. The research employed the God of War (2005), Shadow of Colossus (2006) and Fifa (2010) games, that were musealized from a case study experience at the Computerspiele Museum in Berlin, Germany. According to the authors, the study made it possible to construct the history of games in the form of a gamification dynamics for a Visitor of Games Museum. Five points were considered essential in the constitution of the games and were also present in the construction of the Games Museum: rules, narrative, interactivity, challenges and gameplay.
 -) Research 4 aims to characterize the vision of digital inclusion in extracurricular science spaces and the construction of empirical material is carried out through interviews realized with actors involved in two digital inclusion projects developed in science museums: Clicar Project - University of São Paulo) and Clube dos Descobridores (House of Science - Federal University of Rio de Janeiro).
 -) The text referring to Research 5 describes the process of motivation and development of the Virtual Exhibition "Astronomy: an unforgettable journey", available online on the website of Virtual Museum of Science and Technology of the University of Brasilia (UnB). It is an investigation carried out in the context of a professional master's programme and presents this resource as a product.
 -) The dissertation related to Research 6 makes use of a web-based method (counts of access to a given Internet page) when developing an exploratory research on the visiting public of Fiocruz's Virtual InVivo Museum, using computer methods as Server logging and page tagging) and online questionnaires. In webometrics, according to the two methods

- mentioned by the author, it is possible to follow the actions of the virtual visitor, their responses and interaction with the site.
- J The main objective of Research 7 is the mapping and description of emerging museological practices on the Internet, as well as the technologies that make them possible. The aim being to verify if they cooperate or could cooperate in the realization of the STS ideals (Science, Technology and Society) in online science museums.
 - J Research 8, a thesis, analyzes access to the online pages of associations of science museums on the web, as a gateway to the museums affiliated to them. It is a web-based study that is carried out by means of the survey of factors of impact on the web.
 - J Research 9, also a thesis, focuses on the concept of virtual communities based on repositories of learning objects (LO), which aim to show the possibility of encouraging informal learning in museums by construction of LO by visitors.
 - J The study of the contributions of the Internet in the teaching of Physics is treated by Research 10. The researcher proposes an alternative vision of teaching, based on collaborative projects, entitled "Learning to surf the Internet with Physics; Virtual visits to museums of Physics "Virtual Laboratory-Simulation; Journey to the Solar System; Learning to Save Energy - The Energy Used by Our Home; Living Science; The Physics Classroom and an Electricity Project".
 - J Research 11 describes the elaboration of the virtual world "Space (inter) Space" for the Internet, inspired by the myth of the shamanic voyage of the Kayapó Indians, which evokes the similarity between the shamanic event and the routes undertaken by the spectator in cyberspace. The mentioned virtual world, whose content is based on a scientific project, is also a proposal of thematic exhibition for museums of natural history and sciences that have the ambition to dispose their collections on the Internet.
 - J Research 12, although it focuses on a subject strongly based on informatics, presents quite relevant implications for the education in science museums in terms of developing a system for monitoring visitors and was developed for the Museum of Science and Technology of the Pontifical Catholic University of Rio Grande do Sul (MCT-PUCRS). It is based on the idea of virtual theater, in which users interact with animated actors for the construction and execution of a play.
 - J The text representing Research 13, which also considers MCT-PUCRS as a scenario, describes the process of developing a system with adaptive presentation of information and support for group interaction (Sagres), an environment built on the Internet, which allows the presentation of MCT databases in a way adapted to the characteristics of one or more visitors.

When considering the area of education in science museums, we highlight the 25 year period, 1991-2015, especially since 2000, when 10 of the 13 research studies were carried out. The increased number of studies between 2000 and 2015 may be a result of the increase in the offer of specific courses in the area of science education in the country, after the creation of area 46 by Coordination for the Improvement of Higher Education Personnel (CAPES), entitled "Teaching". In addition, according to the catalog of the Brazilian Association of Science Centers and Museums (ABCMC), Brazil has significantly expanded the number of formal science education spaces outside the formal school environment.

The guide, which gives a brief description of science popularizing spaces around the country, including museums, zoos, aquariums, planetariums, observatories and botanical gardens, is in its third edition and shows a 41% increase in the number of institutions, from 190 in 2009 to 268 in 2015 (ABCMC, 2015). However, there is an uneven distribution of these spaces between the regions of the country. It should be emphasized that Brazil is geographically divided into 5 regions: **North** (comprised of 7 states: Amazonas, Roraima, Amapá, Pará, Tocantins, Rondônia and Acre), **Northeast** (comprised of 9 states: Maranhão, Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, Alagoas, Sergipe and Bahia), **Midwest** (comprised of 3 states: Mato Grosso, Mato Grosso do Sul and Goiás), **Southeast** (comprised of 4 states: São Paulo, Rio de Janeiro, Espírito Santo and Minas Gerais) and **South** (comprised of 3 states: Paraná, Rio Grande do Sul and Santa Catarina), and a **Federal District**, which houses the country's capital, Brasília. Due to the unequal distribution of these spaces, the Southeastern region appears with the largest number of spaces, followed by the South, Northeast, Midwest and, with the fewest number of spaces, the North, which houses most of the Amazonian forest. The distributions are represented in Figure 1, below.

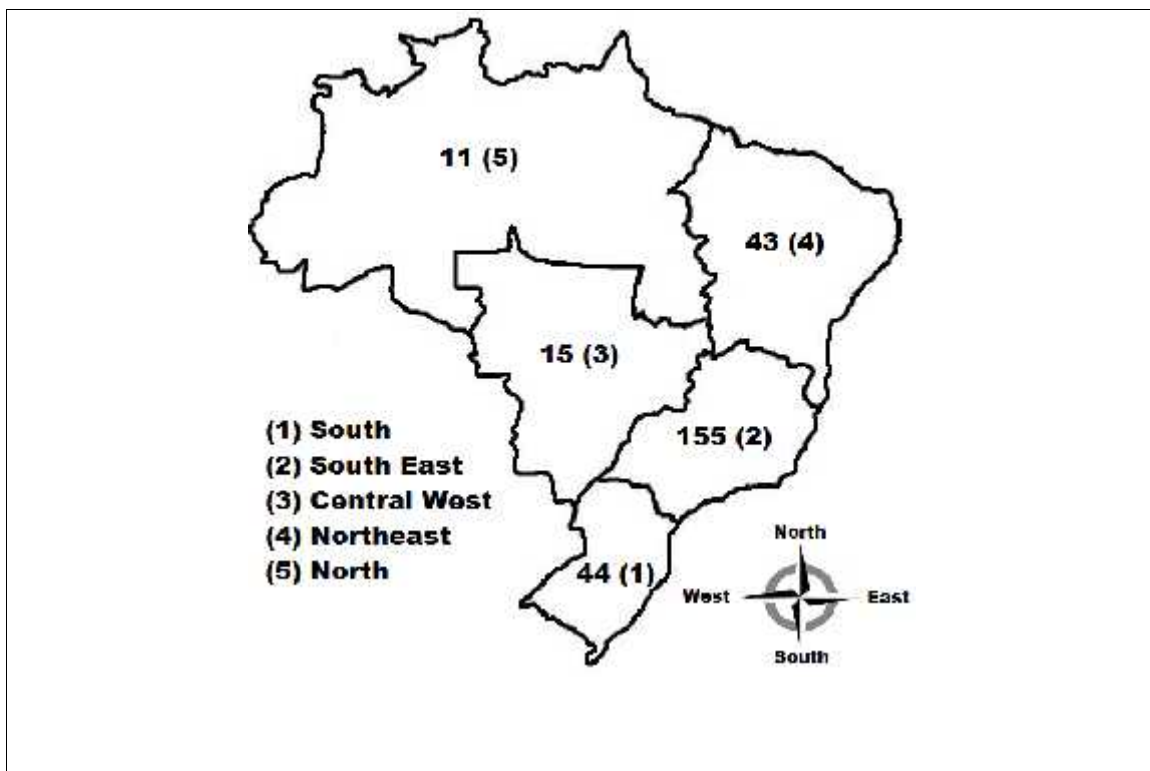


Figure 1: Distribution of the science popularization spaces in Brazil by geographic regions

Source: prepared by the authors based on data from the ABCMC, Guide to Science Centers and Museums of Brazil, 2015.

In the national context, it is possible to infer that Brazilian academic output in education in science museums has been developed as new courses and new concentration areas are emerging, and the existing programmes were consolidated, increasing the number of research studies, as well as the increase in the number of science museums in the country. We note in Figure 1 that the regions with the largest number of spaces of science popularization (Southeastern, with 155 spaces, and South, with 44 spaces) represent the domains with the largest number of universities and research centers in Brazil, the richest regions of the country. This fact has a direct effect on the number of

these spaces. However, it should be noted that this scenario has already improved, that is, data from the ABCMC indicate that in 2009 the Midwest and North regions had only 05 and 06 spaces respectively. After six years these regions had an increase of 200% (15) and 83% (11) respectively, in the number of spaces according to ABCMC data.

As far as research is concerned, when we focus on certain periods, some data comes to our attention. Slongo (2004) points out some data that may help to explain the reduced number of papers related to the area of education in science museums until the year 2000 in the Brazilian scenario. The author reports the concentration of studies on Spontaneous Conceptions and History and Epistemology of Science in the Post-Graduate Programme in Science teaching, offered since 1973 by the University of São Paulo (USP). These indicators are also seen in the Post-Graduate Programme in Education offered by State University of Campinas (Unicamp) and by Science Education offered by State University of São Paulo (Unesp), which had many dissertations and thesis defended in the research area entitled "concepts formation". The highlight of Unicamp, in the Teaching Methodology theme, is related to the temporary Master's programme that was offered at the end of the 70's and early 80's, at the Institute of Mathematics, Statistics and Computer Science (IMECC) of that university. The themes "Teacher Training" and "Curriculum" also appear continuously throughout the period as offerings by several institutions.

In regard to the output of the Brazilian post-graduate programmes, the predominance in the Southeast region, particularly the Rio de Janeiro-São Paulo axis, is considered. With the implementation of area 46 by Capes, related to the teaching of science and mathematics, in the year 2000, there was also a greater recognition of the area and the institution of new post-graduate programmes. This supports the data presented in the ABCMC guides, especially in the unequal distribution in the national territory. Specifically, regarding the research on ICT in science museums, it is worth noting that the results found corroborate previous research, presenting four evolutionary levels of online presence defined by Eler (2008, p. 68-82) as:

- (1) *Sites whose content is limited to the disclosure of institutional information of the physical museum;*
- (2) *Offer on-line services complementary to the face-to-face experience, but not necessarily conditioned to this;*
- (3) *Typical sites of Web 2.0, in which the museum opens several channels of dialogue with its public, encouraging it to participate actively in the construction of the site, either in the register of comments for public exhibition. Also considers in the register for access to personalized and shareable services, in the production of content in various formats, such as audio and video;*
- (4) *Phenomenon of appropriation of the museum by the online and presential ways.*

Although the literature on education in science museums in Brazil has expanded significantly in the last decade, many questions are still posed about learning in these spaces, corroborating the research carried out by Bizerra (2009), which affirms the small number of investigations about virtual museums.

New research and perspectives on practice are placed on education in science museums and ICTs. According to Palma (2009, p. 77), "virtual visitors request more teacher support material, experiences, games, and articles on S&T related topics". They also suggest more interactivity, encouragement for dialogue, promotion of debates and more resources, such as images, photos, infographics and videos.

The diversity of ICT resources to disseminate scientific content is indicative of a hybrid and heterogenous environment in science museums, where visitors can have access through different types of platforms, if the museum is virtual, or digital resources, inside the museum, or both, when

mainstream and alternative paths are available. In a “real” museum, for example, the element of seasonality is quite significant: as visitors search intensely for cultural information during the vacation months, the virtual museum can always contribute to improving access to scientific knowledge (Kyprianos et al., 2019).

It is a fact that we find over a 25 year period (1991-2015), a small number of research studies that related ICTs to science museums, considering the number of spaces spread throughout Brazil. A worrying finding when we consider our immersion in an increasingly technologically and virtually accessible society, including in this framework aspects of education and, in particular, science education. This context naturally becomes an incentive for the development of research and for the discussions on the theme presented, since the school public is one of the most frequent visitors to the Brazilian science museums and they are increasingly connected to ICT.

The ‘digital humanities’, related to science museums, can include public engagement and social participation, two fundamental aspects of interactivity as a strategy for achieving the goal set for these institutions. In the past two decades, interactive elements have been developed and put into practice in museological institutions to offer more immersive, realistic and engaging possibilities. These elements include the incorporation of spaces with motion detection, speech recognition, network installations, tables and multitouch surfaces, resources also addressed in the institutions studied in the dissertations and theses listed above. We agree with Arthur (2018), who noted a change in the emphasis and policy of museums from the moment they start to experiment with ICTs, in order to result in greater appreciation and accessibility by the public. Arthur (2018) also noted the following:

“Historically, museums, like so many institutions, have understood their role as containing, controlling and regulating public interaction with a protected and guarded resource. Authority has been generated through this controlled interaction. The very notion of mediated access rests on the intermediary role of curators and institutions. However, social media now facilitates far greater dialogue between experts and the public, levelling the traditional hierarchies and moving from the one-way information flow to a two-way relationship. Today online communities of interest give new value to the electronic dimension of institutions, sustaining the interest base and attracting visitors through the door” (p. 9).

ICTs bring new possibilities for the presentation of information about museums, not only in the “real” space, but also online, which allows coverage beyond the walls of the museum, and controversial discussion about the nature and central concepts presented in a traditional museum. In this sense, it is important to consider the following: the relationship between object and information, on the one hand, and the relationship between the real and the virtual, on the other. As Schweibenz (2019, p. 21) notes, “although the term and the concept of a virtual museum were created in the early 90s, both are still under construction”. In addition, the central concept of the virtual museum has not yet been clearly identified, and the outline related to the subtle difference between digital collections, online archives and virtual museums needs to be clarified. This seems important because, in the near future, there will be a change in knowledge and experience, as entire generations will be immersed in a virtual world, and will not grow up in the same world as their parents and grandparents. For these generations, the discussion about the “real-virtual division” may seem eccentric, because the future of museums is “the virtual and the real”. The future museum will have a double character (Schweibenz, 2019).

FINAL CONSIDERATIONS

The passage of the science museum as a physical space of visitation to the virtual environment, as well as the incorporation of ICT resources by the physical museum, can (re)signify the

established relationship between this environment of non-formal education and society, including the school. A new reading that expands its sociocultural and civic role, is an environment that forms a participatory culture and questions the scientific and technological aspects of the society in which it is inserted.

Changes are under development when we think of the museological practices on the Internet, since the existence of the same museum is admissible in two instances, one territorial and the other de-territorialized: in this process, the notion of place needs to be rethought. Considering that ICT already integrates the educational resources used by science museums there is, with these possibilities, the opening of new lines of research. The presence of the physical museum and the forms of presence of the museums on the web become subjects to be researched in new investigations that include the transposition of the physical museum to the virtual one, so as to provide to the visitor a fruitful experience the scientific culture.

Thus, the design of online Brazilian science museums presupposes the shift of the focus from the subject/object interaction to the subject/institution and subject/subject interactions; and, from an operational point of view, the adoption of Web 2.0 technologies (interactivity through platforms, applications, social networks, blogs, etc.) and 3.0 (personalized, managed by individual, intelligent websites and applications), which focus on interactivity and collaboration, respectively; in a movement to exchange knowledge from the use of ICT. As in a traditional museum, meeting the public is a key step in any assessment of virtual exposure or making use of ICT resources.

In a traditional museum, the action of staying at the front desk and observing who comes in can provide important directions to guide a public search, action that is not possible in a museum on the web. The importance of an exploratory research that can provide indications for the deepening of the investigations on the public and evaluation of the resources that involve ICT in the science museums should be emphasized. In our research, we sought to identify and describe the main characteristics and trends of the Brazilian research studies of the last 25 years on education in science museums (dissertations and thesis). In particular we were interested in the descriptions that focused on the use of ICT in non-formal education spaces. We conclude that in the Brazilian scenario, such a research approach is still limited, and a new look at this theme is necessary in view of the technologies increasing available to society. We hope that this research does not exhaust this broad and current theme and that our findings may contribute to the emergence of a new research line related to education in science museums.

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