



The Value of Science Centres – especially in low- and middle-income countries

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Author: Guadalupe Díaz Costanzo, Director of Museum Development, Exhibitions and Science Fairs at the Ministry of Science, Technology and Innovation of Argentina

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Executive summary

In recent years, the relevance of scientific and technological culture has become clear: as a society we face many everyday decisions that affect our own health or even broader public issues such as climate change, information technologies or vaccination, just to mention some examples. At the same time, growing evidence supports the critical role of science centres and museums as strategic organizations that can tackle inequalities in people's participation in the science and technology cultural field, especially in low- and middle income countries.

Such centres and museums can impact people and communities in several ways: by stimulating science and technology learning, awareness and interest; by actively involving communities in addressing the Sustainable Development Goals (SDGs); by facilitating local and urban development; and by promoting social inclusion. Ultimately, science centres and museums become relevant in developing more democratic access to science and technology literacy and culture, thus enhancing opportunities of participating in the public debates of our time. Strong and creative efforts should be made to support and develop new science centres and museums and to enhance access opportunities.

This document is intended to provide introductory insight and examples to policy- and decision-makers, enabling them to review the multiple dimensions on which science centres and museums can impact, and why there is an urgent need for science centres and museums within a community, department or city, especially in low- and middle income countries.

Introduction

Science centres and museums are stimulating and inspirational places where **people of all ages, backgrounds and genders** have access to and are part of scientific culture. Indeed, the value of science centres and museums lies in community participation, in the collective development of learning and engaging in activities about science, technology and mathematics, and in the power to transform concepts from the scientific and technological world into experiences that make visitors reflect, think and talk about science, technology and mathematics.

Science learning can occur within a variety of everyday settings, experiences and programmes. These learning activities, usually referred to as informal science learning activities, can pursue complementary goals to those offered by formal school settings. Science centres and museums, which are among the informal science learning settings, can be an effective strategy to contribute to scientific literacy and awareness in societies. Globally, and especially in low- and middle-income countries (LMICs), social inequalities still prevail and deprive people from participation in science engagement activities. For example, results from the latest international assessment in sciences and mathematics (TIMSS, 2019) reflect this disparity among students from high- and low-income countries¹. Moreover, the science scores from the OECD Programme for International Student Assessment (PISA) reflect a similar trend: some low- and middle-income countries lie 30% below the average score². From this broad perspective³, it is important to recall that science centres and museums can help to diminish social inequalities that are reflected in the field of scientific literacy as they bring learning opportunities to people of all ages, cultural and socioeconomic backgrounds.

For the purpose of this document, science centres and museums do not refer to natural history museums (where tangible natural heritage is conserved and exhibited), but to spaces that design different kinds of experiences such as exhibitions, public programmes and school visits based on scientific ideas and inquiry-based approaches. Scientific literacy, following these approaches, stimulates observation, experimentation and critical analysis. Because of their impact on the public – families, teachers, teenagers, etc. – creating new science centres and museums can result in a successful policy to enhance science and technology learning founded on inquiry-based methodologies. With these considerations in mind, it becomes important to mention that key aspects such as initial investment, infrastructure, exhibition design, programme offerings and goals and visions can vary from centre to centre according to local needs and possibilities.

¹ Full rankings and reports from past editions including the latest assessment are accessible at <https://timssandpirls.bc.edu/timss2019/>

² PISA international results are accessible at <https://www.oecd.org/pisa/publications/pisa-2018-results.htm>

³ Global trends are mentioned in a general way although exceptions do exist. However, a detailed analysis of international assessments' results is outside the scope of this document.

Why create science centres and museums?

According to UNESCO, “science centres and science museums are places where people can come together and explore the very mysteries that make up our world. By encouraging public understanding and engagement with science, they serve as important platforms for the empowerment of people, allowing people to make well-informed decisions.” This explanation stresses and focuses both on the people and on their actions. Indeed, science centres and museums are about people and those unique experiences that stimulate, inspire and engage them with science. The science centre or museum and the building in itself make sense when people feel invited to live meaningful experiences about science.

Having a common definition of science centres and museums is a first necessary step before discussing what their value can be. And in order to do so, understanding their potential impact is key. For the purpose of this document, four different dimensions over which science centres and museums can impact are identified:

1. Science learning
2. Sustainable Development Goals
3. Local development
4. The right to science

Four-dimensions why

1. Science learning

Science learning occurs at all ages and in a wide variety of settings: public libraries, parks, botanical gardens, aquaria and festivals, as well as in science centres and museums. According to the **contextual learning model** of John Falk and Lynn Dierking [1], the learning process is influenced by personal, social and physical contexts. The personal context refers to visitors’ emotions, motivations, previous knowledge, beliefs and attitudes. It could be regarded as the personal agenda each visitor has. The social context refers to the fact that learning is also influenced by a cultural and historic context as it is also a social experience. Finally, the physical context means that learning is influenced by external stimuli from the space: sounds, smells, images and tactile experiences. This three-fold learning model recognizes that different visitors in a science centre or museum could have different experiences even while doing the same activity or visiting the same exhibition. Therefore, developing effective programmes and exhibitions means valuing visitors’ previous knowledge and emotions. The widespread instinct places schools and formal education settings as the main environments where science learning occurs, however, science learning can occur in other settings [2]. Indeed, a very graphical estimate taken from results in the USA mentions that people spend, on average, 95 percent of their lifetime in out-of-school settings [3]. In 2016, the same authors designed an international study to understand the effects of science centres on scientific literacy (attitudes, values, public understanding, etc.). The research, carried out in 13 countries (including mostly middle- and high-income countries) involved more than 6,000 adults and showed that individuals who visited science centres had significantly higher interest, understanding and identity relative to science and technology than those who did not [4].

The complex process of learning (including science learning) rarely develops from a single source [1]. Instead, it is a progressive process which is developed over time from a wide variety of experiences that include watching a film, reading a book, discussing ideas with friends, navigating the internet or going to a science centre, among many other everyday examples. Because learning depends a lot on personal and social dimensions, it becomes an important aspect to create and develop more opportunities that welcome people from all ages, cultural and socioeconomic backgrounds and genders and facilitate their access to and participation in experiences related to science, technology and mathematics [5].

The experiences related to science, technology and mathematics that a science centre or museum can develop are varied. During recent years, science museums have pro-actively diversified the programmes they create to be more community- and people-oriented, which is both remarkable and necessary. That said, science learning in general, and science learning

in out-of-school contexts in particular, is a field of research in itself which, for the purpose of this document, has been broadly introduced. The following subsections refer to different aspects that, together with cases and examples, illustrate the potential that science centres and museums have in science learning.

Learning by doing

The popular meaning of “science” is frequently related to specific scientific knowledge (and that is perfectly correct). However, science is more than its corpus of knowledge. Science may also refer to how knowledge is achieved and, ultimately, has to do with the curiosity that encourages people to discover the mechanisms that rule the natural and social world using specific methodologies. Inquiry-based science education (IBSE) is an approach to teaching and learning that challenges the way students think. IBSE stimulates the development and investigation of scientific questions that satisfy students’ curiosity through experimentation. It encourages students to make observations, elaborate conjectures, analyse evidence and develop arguments and possible explanations to certain phenomena.

IBSE has been proven to be a successful process for teaching and learning that can be applied in science classrooms as well as in many other science learning settings such as science centres and museums⁴. In fact, workshops as well as design exhibits in science centres and museums usually follow and stimulate the IBSE approach. The Smithsonian Science Education Centre (SSEC) in the USA is an international reference point in this regard. Together with evaluators from the Centre for Research in Educational Policy (CREP) at the University of Memphis, for example, an extensive study was conducted that involved thousands of students implementing the SSEC’s inquiry-based science programme. The results, which are fully available online⁵, demonstrated improvements in science learning as well as in reading and mathematics.

For this reason, many science centres and museums usually develop programmes to improve IBSE in different situations and over a wide range of topics from the natural and social sciences.

A place for teachers



Many programmes and experiences reveal the transformative value of science centres and museums for science teaching. Teacher programmes can vary in objectives, methodology, extension and impact [6]. Several years ago, the Exploratorium from San Francisco (USA), one of the world’s most distinguished science centres and certainly a pioneer in many aspects, developed a training programme for teachers in which inquiry-based science learning was encouraged. During the activity, teachers could first experience the exhibits and then design their own visit with their students [7]. These kinds of programmes encourage teachers to be in charge of their own learning visits and design a path according to their needs. Nowadays, the Shanghai Science and Technology Museum in China – during a 20 hour professional training course – focuses on strategies to explore the science museum as well as science teaching approaches. Horno³ in Monterrey (Mexico) designed a workshop for teachers so as to promote the interaction

with scientists and to associate scientific ideas with everyday life experiences using a problem-to-solution methodology [8]. Despite such different programmes, it is important to recognize the potential of science centres and museums as valuable settings that give new learning opportunities for teachers. Science centres and museums are distinctive physical contexts that can become a powerful resource for both science teachers and educators.

Science engagement through the arts

Science centres and museums are ideal places where to explore creative alliances and partnerships that give rise to new conversations and experiences. However, in the past few decades, science centres and museums (as well as many other organizations) have explored science communication events that combine arts and sciences. In doing so, efforts focused

⁴ <https://www.interacademies.org/publication/case-inquiry-based-science-education-ibse>

⁵ <https://ssec.si.edu/laser-i3>

⁶ <https://www.horno3.org/>

on their convergence so that the *two cultures*⁷ might fuse into memorable and effective science communication experiences. Science communication through the arts can be achieved in several ways and by promoting programmes or actions that can be effectively led by science centres and museums.

Among the examples of exhibitions that achieve a genuine combination of art and science, some of the most remarkable are those created by Science Gallery, in the city of Dublin. Science Gallery displays only temporary exhibitions put together from submissions of proposals solicited via open calls to artists, scientists or mixed teams. From a different perspective, prestigious scientific research centres like CERN have developed successful artist-in-residency programmes. Artistic residencies in science centres and museums can also be an effective way to create plays, performances or writings that are inspired by and based on science. Science and theatre also have a history of connections that may be used effectively by science centres and museums to produce already existing plays and/or create new ones. This is the case of the science museum *Museu da Vida*, in Rio de Janeiro, Brazil, that frequently encourages collaborations between artists and scientists and in 2016 premiered 'Life of Galileo', by Bertolt Brecht [9]. Another way to develop cross-disciplinary practices is through workshops oriented to scientists in which known tools such as improvisation, media training and writing can be applied to science communication. These kinds of practices enrich dialogue among artists and scientists and can provide great opportunities to create a local team of scientists with interest and expertise in science communication.



'Life of Galileo' staged at Museu da Vida in Rio de Janeiro, Brazil, in 2016 – a collaboration between scientists and artists. Photo: Renato Mangolin.

Options for policy- and decision-makers: Science learning and engagement

Encourage and support science centres and museum's learning programmes.

Develop inquiry-based science teaching programmes.

Consider science centres and museums as strategic partners in the professional development of science and technology teachers.

Support science centres and museums to host science-art festivals, conferences and workshops and collaboration between art and science organizations.

⁷ Art and science have gone through stages of unity and separation throughout history. Charles Snow explained the strategic importance of bringing together science and humanities in his well-known book *The Two Cultures and the Scientific Revolution*.

2. Sustainable Development Goals (SDGs)

The current global challenges are represented in the SDGs and have been widely adopted by science centres and museums. From programmes that address gender equality (including girls' and women's participation in science and technology) to experiences about climate change, the impact of our ways of living on the ocean, and awareness about health and well-being, meaningful participation and invitation to action may be catalysed by science centres and museums around these common goals. The complexity and interconnection of these global challenges demands – among other actions – scientifically reliable information and social participation, two aspects that science centres and museums can foster. Adopting the SDGs as part of the local agenda is vital for low- and middle-income countries since many issues that underlie the global agenda pose an unequal impact on societies and vulnerable populations in such countries.

Because most SDGs are underpinned by the natural and social sciences, public activities and cultural programmes can be oriented to improve community participation in these relevant topics. For instance, the Science Museum in London (UK) developed *Our Future Planet*, a special exhibition that invites visitors to fight against climate change. The exhibition, accessible during the 26th UN Climate Change Conference of the Parties (COP26) in the UK, explores the technologies being developed to remove carbon dioxide from the atmosphere and showcases nature-based solutions being developed to trap carbon dioxide released by human activity, notably the burning of fossil fuels.



The gender gap

The gender gap in science, technology, engineering and mathematics (STEM) fields is a global concern. As highlighted in the UNESCO Global Education Monitoring Report 2020, gender continuing inequalities in various fields of study constrains girls' choice of careers and equality in work opportunities [10]. The report mentions that in the 37 OECD countries participating in the 2018 round of PISA, 7% of girls but 15% of boys expected to work in science and engineering professions. The report also points out that the gender gap was particularly high in Colombia (10% of girls, 25% of boys) and Mexico (11% of girls, 30% of boys). Another result extracted from the 2018 edition of PISA reflects that only 14% of girls who were top performers in science or mathematics expected to work in science and engineering, compared with 26% of top-performing boys [10]. Also, women are still a minority in scientific and technological disciplines

such as information technologies, computing, physics, mathematics and engineering [11]. Worldwide 33% of researchers are women but, for example, this number is just 22% in the field of AI (Artificial Intelligence). This situation, together with career prospects, could lead to women being excluded from the future digital job market. The current scenario evidences the urgent need of connecting efforts from different sectors, including educational systems. Education in general, and STEM education in particular, is critical for women's rights.

As mentioned throughout this document, the so-called informal learning settings – such as science centres and museums – can jointly work with schools, universities and government to become local actors that actively work with the community to reduce the gender gap in science and technology, inviting girls and women to participate whatever their age, abilities, or cultural and socioeconomic background. In this sense, science centres and museums can offer and develop a wide range of programmes and instruments to address the gender gap in STEM. For instance, an active way of adopting a gender inclusive perspective in science centres and museums should be integrated into their conceptualisation. Considering girls and women when designing of STEM exhibitions and educational programmes is also a requirement. For example, the Exploratorium in San Francisco (USA) developed a female-responsive design framework that includes different design strategies to represent females and their interests, provide meaningful connections, create low-pressure settings and enable social interaction [12].



Social inclusion

Structural inequalities are an urgent matter especially in low- and middle-income countries and their consequences impact on access to and participation in scientific culture. A study that considered science and technology perception survey responses in four Latin American countries (Argentina, Brazil, Chile and Panama) arrived at the conclusion that the great majority of people with low educational and socioeconomic status (72.9%) did not visit any organization related to science and technology. These data represent half of the middle class population that completed secondary school studies and a quarter of Latin Americans with higher education and socioeconomic status [13]. Another study, from the UK, used a qualitative study to explore how exclusion and nonparticipation occurred in science centre and museum settings. In order to do so, it analysed experiences and perspectives of people from disadvantaged social positions before, during, and after visiting an institution of their choice. Among the findings, participants described their reasons for not usually visiting science centres and museums, and informal



science learning organizations in general, in terms of their expectations and assumptions, as well as logistics [14].

Concerns in this regard lead to mention specifically that it is crucial to develop more inclusive science learning opportunities that consider and invite people from different ethnic backgrounds, income, or place of residence, since these factors play a significant role when it comes to understanding that publics have unequal opportunities to access science and technology [14]. For this reason, social inclusive practices should be consciously taken into account by science centres and museums. It is a mindful decision to become an organization capable of self-reflection and

of identifying possible unintentional behaviours or situations. For example, it is important to recognise that every museum exhibition is inevitably influenced by the cultural assumptions and resources of the people who make it [15]. In this paper [15], the author gives several examples from her own experience in developing international exhibitions that were originally from the Exploratorium in San Francisco (USA). In Caracas, Venezuela, she explains, one exhibition was mounted using bright colours (instead of the neutral ones used by the Exploratorium) since such colours would better reflect the local culture. The language used and the design of exhibits and programmes should be carefully developed in order to be inclusive. When exhibition design allows it, visitors will try to use their own knowledge, languages or cultures to make sense of it [14]. Moments of cross-cultural meaning-making have great potential for creating more inclusive science learning opportunities [14]. Strategies that promote an inclusive model consider different voices, spaces and publics and actively involve the whole museum team (from communicators to architects). From exhibition design to specific programmes, effective social inclusion programmes and actions must avoid the possibility of excluding, albeit inadvertently, the already socially marginalised.

Healthy lives

As reliable and trustful communication spaces, science centres and museums have played an active role in serving their communities by communicating about disease prevention, nutrition, and also by developing programmes for people suffering from diseases such as autism, dementia or Alzheimer's. In fact, the current pandemic of COVID-19 gave rise to several health communication strategies by science centres and museums. Science Gallery Bangaluru in India, for instance, developed the online exhibition Contagion⁸, aimed at developing relevant questions and informing about epidemics. The online site offers live sessions, activity handbooks and an extensive science, medical and artistic programme.

Also, in the past ten years, there has been growing evidence of the impact of cultural engagement in health and wellbeing [16]. This area of research that connects experts from the museum, education and health sectors appears to be a promising field for the assessment of urban planning and public policies. Research suggests that visiting museums and exhibitions enhance our quality of life by encouraging cognitive stimulation, social interaction and creativity. Also, museums are ideal places to develop volunteering programmes, an activity that can improve mental and physical health, at least for the elderly [17] [18]. For example, the Two Oceans Aquarium⁹ (South Africa) has an extensive volunteer programme for those interested in marine sciences and environmental topics: the aquarium has special programmes for adults, high school learners and those interested in diving and feeding the animals.

⁸ <https://nowtransmitting.com/>

⁹ <https://www.aquarium.co.za/>

Options for policy- and decision-makers: The SDGs and science centres

Consider gender equity for decision-making and advisory positions in science centres and museums.

Support the participation of girls and women in science and technology learning programmes.

Implement and support specific practices that help vulnerable communities access the science centre and museum.

Work in collaboration with health and medical organizations to identify possible learning programmes and implementing volunteer programmes, especially for the elderly.

3. Local development

Museums in general, and science centres and museums in particular, are most known and recognised for their contribution to the process of learning and engagement. However, as cultural agents, they can contribute in the short and long term to the economic development of their cities and countries. The creation of new jobs and, if there is a paid entrance, the revenue obtained by paid tickets, are the most common factors considered to assess their contribution. However, these two aspects provide a partial analysis of their importance in economic development processes. For example, science centres and museums can generate benefits in tourism. In this sense, the opening of new science centres and museums is an opportunity to associate with local tourist offices and other local touristic sites. Also, developing multi-access cards or passes at local or regional levels can be a useful way to strengthen a network of services that may include benefits or discounts in areas such as cultural venues, gastronomy enterprises or bookstores, just to mention a few.

The economic impact of science centres and museums can also be stimulated by active participation in networks and agreements with different stakeholders: from organizations such as universities, start-ups, private companies and government dependencies, to researchers, artisans and local or regional manufacturers. As mentioned in the Guide for Governments, Communities and Museums from the OECD and the International Council of Museums (ICOM), any museum should be considered a *hub of knowledge* [19]. With this definition in mind, it therefore becomes vital to promote healthy partnerships between museums and different economic actors.

As for any cultural and creative industry, public funding and support is essential. However, most museums, and science centres and museums in particular, develop a mixed model in which private investment and individual giving can also be relevant. As for the purpose of this document, it is important to recall that it is essential that local and/or national governments work in close cooperation with science centres and museums to achieve best results and guarantee their sustainability over time.

From an urban development point of view, museums can shape and change several physical and dynamical aspects of a city. Building a science centre or museum, or renovating an existing building, would create a new place for open meetings that attract specific publics. For instance, the large esplanade in the surroundings of the Museum of Memory and Tolerance in Mexico City has become a meeting point for young dancers who are able to watch their choreographies reflected in the museum's shiny glass windows. Appropriation of public places may help people feel proud of their neighbourhood and city, it can inspire new cultural expressions, encourage social interactions, and be physically and mentally stimulating. In order to get out the most from a new cultural space, urban planners and cultural agents must sit at the same table to share possibilities and expectations. In addition, community participation at this early planning stage should be considered: holding conversations with local salesmen and women, schools and families will help to identify cultural needs and habits.

Options for policy- and decision-makers: Local development

Create instruments that promote local or regional associations (funding, tax relief, etc.) Ensure clear communication channels with the science centre or museum in order to increase its contribution to local development.

Support and encourage travelling science exhibitions and cultural programmes.

Consider working together with urban planners, cultural agents and the community in order to design an inviting public space.

4. The right to science

Article 27 of the Universal Declaration of Human Rights states that “everyone has the right freely to participate in the cultural life of the community, to enjoy the arts and to share in scientific advancement and its benefits.” This means that everyone has the right to be aware and benefit from scientific advancement but, most importantly, it also means that people should be able to be actively involved in science. Naturally, this does not mean to be a scientist but, for example, to be able to be part of local and global public debates that concern scientific and technological issues. Current and future debates are highly influenced by the advancement of science and technology: from climate change and genetically modified crops to vaccination, big data, plastics and fisheries, to provide a few examples.

It is important to mention that there are several possible instruments to facilitate access to scientific culture. Participation in science and technology can also be promoted by online resources, TV and radio shows, science film festivals, viewing science plays and theatres, and visits to botanical gardens, libraries and cultural organizations. However, science centres and museums play additional significant roles in scientific learning: promoting an engagement with creativity among children and adults, and actively working to ensure that diverse people access these opportunities at all stages of their lives.

Options for policy- and decision-makers: The right to science

An inviting democratic place for scientific culture should facilitate engagement and inspire debates among the local and scientific communities.

Develop strategies to invite and actively encourage people to visit the science centre, avoiding that some potential visitors may feel excluded.

Develop programmes that encourage dialogue and reflection about science and technology in everyday life

Identify the groups that are not visiting the science centre: understand why they don't go.

Planning science centres and museums

The success of science centres and museums largely depends on the planning and design phases. Identifying clear objectives – as obvious as it sounds – developing a network of future stakeholders, and involving the local community will be substantial steps towards creating a space that becomes a centre for scientific learning relevant to its community.

A process to enjoy

Not many people (not even all museum experts) have the chance of thinking from scratch about a new science centre or museum. Being part of such a unique and wonderful process is a transforming opportunity for those involved at the different stages. Detailed planning is important, but enjoying the process is a necessary condition to real success.

Planning is a broad – sometimes even scary – term that should sound familiar to those who are working in a science centre or museum: returning to and discussing the centre's founding ideas and manifests should be a periodic attitude in an organization that acts and dialogues with the changing needs of its community. Preplanning and planning are crucial stages needed to develop a new cultural institution, and specifically a science centre or museum. Although planning may not sound as fascinating as designing, developing scientific contents or exploring public programmes, it is a defining and creative phase during which the main purpose of the science centre will be discussed. As mentioned several times in this document, it would be a mistake to suggest that a fixed step-by-step procedure would work for all new organizations; however, it can be useful to highlight some good practices [20].

The **preliminary planning** or preplanning stage should consider all the general aspects that go from the location and the building itself, to the available budget, with the aim of defining the project. In order to make that happen, during this stage it is highly recommended to identify the planners, their roles, and to name **decision and advisory committees**. Both the planning team and the committee/s should be diverse and include all those different voices that the future science centre will talk to. In other words, the diversity of visitors expected to frequent the science centre should be reflected in the committees. For example, if we expect to develop and foster science teaching programmes, we should consider including schools and teachers in the conversation. Also, committees should consider gender equity and active experts who come from different required backgrounds: exhibition design, museum education, science communication and management, etc. Museum experts in education deserve a special mention since they are the experts in visitors and publics and their view will be very valuable from the very beginning.

Building, planning and designing a new science centre or museum is a unique opportunity to encourage a **bottom-up strategy** in order to promote conversation, which, according to the planning and designing specialist Kathleen McKlean is “the most powerful form of participation in which a museum can engage” [21]. Moreover, this author argues that the visitors will bring their own expert knowledge that should dialogue with the museum expert knowledge. For instance, asking future visitors what they think about the ideas developed by the museum experts is a real way of including their expert views. With this valuable recommendation in mind, it should be easy to recall that besides available budgets and buildings, each future science centre or museum will walk its own and unique path, in part because of its own local community.

The institutional planning stage, which can be understood as a subsequent step, discusses the mission and objectives of the science centre or museum. It can be a difficult stage, during which it is important to have clear communication, since agreed objectives will guide subsequent steps. To consider are: In which ways will the science centre and museum transform visitors' lives? To what extent will it become a place to gather diverse publics? Are there any scientific topics or disciplines that are of local or national relevance? Should visitor-oriented or science facts-oriented designs be considered? This last question is just an alert to frequently encountered situations where the focus shifts towards the scientific knowledge itself while unintentionally leaving visitors' interests and emotions aside.

The effort made to identify the mission and objectives of the science centre of museum will soon become a firm first step, since founding documents are useful resources to discuss further

with the local community and potential stakeholders (local government, national universities, private companies, NGOs, as well as other science centres). At this stage, it can be very inspiring and useful to visit and establish contact with museum experts from other museums (all kinds of museums) or existing local science learning and communication programmes. The insight from the scientific community is also very valuable. Science and medical academies¹⁰ are ideal organizations to dialogue with since they gather experts with extensive and outstanding trajectories at national and international levels.

From a financial point of view, it is important to consider that costs will gradually increase from the preplanning stage to the opening and operating stage [20]. Having this consideration in mind will help to accomplish the project and achieve its sustainability. For example, it will be important to discuss whether the science centre or museum will have possibilities of raising revenue (either by ticket sales, renting halls and rooms, or opening a cafe or gift store). Despite any of the previous possibilities, the support from the local and national government is always crucial for cultural institutions.

The schematic and final design stage will be more effective once careful planning has been made. Deciding the purposes of the different areas and places in a science centre – as well as developing its exhibitions – should come only after discussing and deciding the nature of the project as well as after involving different sectors at the decision-making table.

Places to experience

In the end, and as mentioned in the UNESCO definition cited earlier, planning science centres and museums means to plan places to experience. Those places can be as diverse as buildings that are specially designed for the purpose, renovated buildings that in the past had other purposes such as factories, clubs or city establishments, or halls and rooms in schools or universities and spaces in public squares and parks.

Depending on the identified objectives, the available space and resources, the following sections briefly characterise possible uses and typologies. This list is an attempt to demonstrate the heterogeneous yet complementary spaces that may constitute varied science engaging and learning environments.

Exhibition halls

Most science centres and museums have exhibition halls that are intended for the installation of permanent and/or temporary exhibitions. It is important to note that *permanent* exhibitions should not be considered permanent in a literal way. Prior to their development, it is recommended to have an estimated timeframe during which the exhibition is supposed to be available. In fact, for every science centre or museum, the idea of *permanent* could mean different periods of time. Keeping this idea in mind, developing permanent science exhibitions encompasses aspects that differ from aspects considered for temporary exhibitions. For example, in a permanent exhibition it is crucial to consider the development of the main topic for future years. If, for example, the permanent exhibition is about neuroscience, is neuroscientific knowledge expected to change in the next few years? Will the science centre be able to update the information and the exhibits? From a structural perspective, materials used for permanent exhibitions also differ from the ones used in temporary exhibitions as they are intended to last longer and resist the manipulation of – probably – thousands of visitors. Exhibits containing digital interfaces also deserve a special mention since hardware and software usually need repairs and updates, respectively.

Temporary exhibitions, in contrast, can last a couple of months and – more importantly – can provide great opportunities to develop collaborative programmes with the local community. For instance, these kinds of exhibitions could address topics that have been previously surveyed, thus focusing on topics that foster the curiosity local people or respond to their specific interests. Also, they could address topics that are temporarily being debated in the public arena or that consider a local concern. From another perspective, temporary exhibitions can be valued programmes because of their own processes: people may be invited to participate in the design process thus contributing their views, experiences and thoughts to the creation of the exhibition.

¹⁰ <https://www.interacademies.org/network/member-academies>

Makerspaces and fablabs

Makerspaces and fabrication laboratories, or FabLabs, are spaces for digital and physical creation that work under the values of open knowledge, collaboration and cooperation. Because of their open and self-paced nature, these places may serve as unique learning platforms where ideas turn into innovative developments and solutions by means of affordable – and very valuable – technologies, and where learning experiences are shared and exchanged.

Since the FabLab concept was first designed in 2001 by Neil Gershenfeld from the Media Lab of the Massachusetts Institute of Technology in the USA [22], these community-oriented spaces have opened all around the world¹¹. From a practical point of view, they are usually equipped with affordable technology that include 3D printers and scanners, computer-controlled milling machines, a laser cutter, electronics and circuit boards for prototyping. However, it should be mentioned that in a similar way that the success of science centres and museums can be evaluated by considering the learning experiences lived by their visitors, the success of FabLabs and makerspaces lies in the community engagement and learning projects developed. That is, their potential surpasses the available technology.



Demonstrations at the Trieste Mini Maker Fair, 2016. Photo: Massimo Goina, Luca Valenta.

FabLabs can be developed in association with or under programmes run by universities, schools or science centres and museums, or they may work independently. For instance, the University of Nairobi in Kenya has a fabrication laboratory mainly oriented to entrepreneurs and graduates from engineering that improve and prototype their ideas in the FabLab. They have also developed a programme in robotics specially oriented for underprivileged children and teenagers from Nairobi that seeks to encourage them into hands-on practices¹². Another example is the FabLab Campana in Monterrey, Mexico, that works in the facilities of a high-school located in a place characterized by its vulnerability and marginalisation. As detailed and carefully investigated, “the FabLab Campana has provided a platform for the democratisation of educational practices through the inclusion of participants from different settings, countries and ages, collaborating in the achievement of common goals” [23]. Although not defined by its creators exactly as a makerspace, the Dreamspace Academy¹³ in Sri Lanka is an internationally

¹¹ <https://fabfoundation.org/>

¹² <https://fablaboutreach.wordpress.com/>

¹³ <https://dreamspace.academy/pages/1-0-index.php>

awarded initiative that supports the development of solutions to tackle local issues based on the makers' spirit. Among the several activities, they develop programmes on technology education for women and digital media ethics. Also, some public activities might unpin from the active FabLab or Makerspace as reported by the Scientific FabLab¹⁴ that is run by the Science Dissemination Unit of the International Centre for Theoretical Physics (ICTP), in Trieste, Italy. As carefully reported by their organisers, developing free public expos become extraordinary opportunities for gathering makers together, exchanging ideas and promoting local community participation [24]. FabLab Khairpur of the Sukkur IBA University in Sukkur, Pakistan, is another example of using such facilities for building the capacity of youth and communities¹⁵.

Laboratories and workshop rooms

Laboratories might be perfect spaces to engage visitors with hands-on experiences. Either family oriented activities or teacher professional development courses can benefit from places where benches and laboratory materials are available and offer the possibility of engaging with science through IBSE methodology. On the other hand, workshop rooms are versatile spaces where conferences, courses, school visits, public meetings and other learning and cultural programmes may occur.

The School Children's Palace in Almaty, Kazakhstan, aims to provide the younger generation with a positive goal, means for achieving it and the surroundings for activities based on different interests. Built in 2011 through an initiative of President Nursultan Nazarbayev, Palace offers a variety of activities from scientific to artistic to sports to help schoolchildren develop skills outside the classroom¹⁶.

Libraries

Libraries are strategic places in science centres and museums: they can foster curiosity through science reading, host special programmes such as school visits, teacher training activities, or public presentations of science and technology-related books, as well as helping visitors to return in search of information. Currently, libraries may refer to welcoming places with only virtual resources, books and special magazines or, ideally, a combination of both. In the context of science centres and museums in low- and middle-income countries, such libraries can improve opportunities to access materials and technical information as well as to participate in science learning programmes.

Outdoors: terraces, gardens and parks



Many science centres and museums have outdoors spaces (terraces, gardens or parks) that may be planned as science learning environments and public meeting points. These places can be designed to focus on certain scientific topics as diverse as botany, water, astronomy or palaeontology. Given the needs for the development of sustainable agriculture, outdoor spaces in science centres and museums can be special locations to promote family farming and agroecology. Special programmes could be developed in cooperation with the community and local partners in order to contribute to the development of regional economies and

healthy nutrition, as in *Yaku Parque Museo del Agua*¹⁷ in Ecuador. Twice each month, workshops about seeds, sowing and urban agriculture are carried out in a nearby orchard in collaboration with a centre for the elderly, while promoting conversations on social memory and food sovereignty. Outdoor spaces offer great options to expand science learning programmes and increase the opportunities of public participation.

¹⁴ <http://scifablab.ictp.it/>

¹⁵ <http://fablab.iba-suk.edu.pk/>

¹⁶ <https://astanatimes.com/2016/10/capitals-childrens-palace-helps-children-develop-outside-the-classroom/>

¹⁷ Yaku Museum Park of Water (<http://www.yakumuseoagua.gob.ec/>)

Options for policy- and decision-makers: Planning science centres and museums

Establish planning and advisory committees that include experts from different disciplines and community representatives (teachers, students, etc.).

Identify objectives, local needs and community interests before designing a science centre and/or new exhibits.

Consider the science centre or museum as a potential partner for funders.

Establishing science centres and museums

Science centres and museums come in all sizes and shapes. A science centre can address a specific topic, such as climate change, or different disciplines from among the sciences. The majority of science centres and museums focus on children and families but many others on youth and adults; some have mostly permanent exhibitions and some plan only temporary exhibitions; some consider art and science practices to be at the heart of their institutions; and others focus on the open use of new and emerging technologies. Because of the rich variety of science centres and museums, there is no one-size-fits-all approach to define how it should be made. However, some good and general practices can be identified in an attempt to create an active science centre or museum.

Never alone

Science centres and museums belong and contribute to the science and technology education system. Considering the institution as part of a larger network of organisations – as well as being open to explore genuine collaborations – may allow it to create value, achieve larger impact, and work in a more efficient way.

Partnerships are essential for museums, and working with other organisations should be among the core values of any cultural institution. In fact, if no collaborations are promoted, it would imply that a single organisation is capable of assuring all of its needs. This implicit message can be both wrong and harmful, especially for the museum workers and the visitors' experience.

There are different kinds of partners and different kinds of partnerships. Common partners for science centres and museums may vary from schools, universities, educators, local or national governments, funders, or other science centres. Partnerships can vary in their intensity, kinds of agreements or the agreement period over which they extend.

For almost any science centre or museum, school partnerships are among the most valuable collaborations. The school visits and programmes help both the museum and the school to bond and create long lasting relationships of importance to the community. However, it is critical to understand the partnership as a relationship in which all parties provide their own value [25]. In this sense, schools and museums should be seen as peers. When considering schools as peers, meaningful joint projects may arise: visits, exhibits and exhibitions can be co-created with teachers and students; moreover, educators can participate in pilot actions in order to consider their views and feedback, just to mention some cases. Science centres and schools can work together in order to develop a greater sense of belonging to their communities by engaging students with science and technology.



Educators at C3 of the Ministry for Science, Technology and Innovation of Argentina.

It is essential that science centres and museums work together with local scientists and researchers, who should almost be considered as critical parts of the science centre and museum. They can – and should – serve as advisors in the development of programmes and exhibits, and be invited to present, on stage, at various workshops and conferences. Among the many examples that can be given in this regard, the National Museum of Emerging Science and Innovation, Miraikan, in Tokyo, Japan, is an outstanding one, since research facilities and exhibition halls are located in the same building, thus converting professional research laboratories into science communication facilities as well.

National Universities can also become valuable partners for science centres. At the Centro Cultural de la Ciencia (C3)¹⁸ of the Ministry for Science, Technology and Innovation of Argentina, around 30 higher students from the sciences and humanities are accepted annually to become educators at C3. Open calls are launched in agreement with participating national universities and, during a two-year period, the selected scholars learn about science communication, education in museums, and also about the science topics relevant to the current exhibitions.

¹⁸ Cultural Centre for Science (ccciencia.gob.ar)

From small local projects to universities or funders, it is critical to identify needs and goals and to develop a trustful relationship in which clear communication would be the key to success. Because in the end, partnerships can be seen as a dialogue with several decision-making processes in between. The role of policy and decision-makers in this regard is critical, as there exist several instruments to stimulate and support meaningful partnerships in museums.

The science you give, the science you do

Evaluation is a vital tool in science centres and museums. It is fundamental when the institution wants to develop, plan or change programmes and, most importantly, it is a strong instrument to establish a meaningful dialogue with the community. Evaluations that are people-centred and with clear purposes or goals will help build a stronger organisation in which the institution supports science and evidence in the same way they communicate.

Implementing surveys, focus groups or other evaluation strategies are instances of dialogue and science communication. The field of evaluation and visitors' studies is an area of expertise in itself and, when planning to do it for the first time, it will be important to contact specialists that may assist during the process. Alternatively, some science centres and museums have their own experts dedicated to carrying out systematic and periodic studies. An important aspect to consider about evaluation is honesty: if properly designed, evaluations are not done to tell us what we want to hear, but what has actually happened.

Science centres and museums can also support research from the local scientific community: being an open organisation to be studied can become an effective science communication tool in itself that creates value from the experiences carried out in the science centre.

Options for policy- and decision-makers: Making science centres and museums

Provide science centres and museums with opportunities to renew their materials and infrastructure.

Support innovation and change: science centres and museums are naturally changing organizations.

Encourage scientific research in science centres and museums: organizing open calls for researchers can be an effective strategy.

Motivate participation in national and regional networks and support the assistance of museum professionals to the meetings – it can be inspiring and can lead to new ideas and partnerships.

Establish, from the beginning, effective monitoring and evaluation systems.

To do list for planning and establishing science centres and museums

1. **Write and document:** You don't need to be a novelist to put down ideas about what you would like visitors to experience in the science centre. There is always a moment in which documents are only one-page long. Try to write clear ideas and sentences starting with "I wish visitors could ...".
2. **Contact museum experts:** Hold informal conversations with museum experts. Share your plan and ideas: the museum community is very open and is always ready to share good practice, even if you do not come from the field and, for example, are a scientist.
3. **Define clear objectives:** Conversation, surveys and focus groups can help during this initial phase. Test objectives and be open for a change. Objectives should be about the visitors and how the science centre will have a positive impact on their lives and the local area.
4. **Science, technology and mathematics** are more than knowledge and equipment so it will be crucial to understand what aspects of science, technology and mathematics the organization wants to develop. (Yes, this should be included in manifestos and founding documents.)
5. **Write your own story about science:** Exhibitions, as well as learning and cultural programmes, will be telling a story about science, scientists, recent discoveries or the still unknown. Science centres and museums and science learning programmes are about narratives.
6. **Science centres and museums** need to cultivate a genuine dialogue with the scientific community so they can count on each other. Invite them to be part of the process and discuss ideas together.
7. **Prototyping** is a must in museums in general, and in science centres in particular. For both exhibits and workshops, try first to see if it accomplishes the expectations and, if not, be open to make changes.
8. **I learn, you learn:** Science centres and museums need passionate and committed experts whose professional development should be highly supported. Different areas in a science centre or museum require specific knowledge.
9. **Why would people visit the science centre or museum?** The fact that a public space exists does not mean people will go. Try to identify the reasons why visitors (and non-visitors) go (don't go) and make answering this question a self-reflective habit.
10. **Keep on writing and documenting:** Pictures, videos and written documents (e.g. news items) will help the museum team go back, rethink and, last but not least, tell the story of the science centre or museum in the future.

Conclusions

As global challenges and everyday life decisions are increasingly influenced by scientific breakthroughs and technological development, policies to strengthen science and technology education systems become necessary and strategic. In addition, the fact that social inequalities are most frequently reflected in access to and participation in scientific culture should raise special concerns in countries facing larger inequalities.

Science centres and museums can be transformative spaces where teachers and students engage with significant science, technology and mathematics learning experiences through inquiry-based methodologies. Those experiences, from exhibits to workshops, may result from the meaningful participation of the local community, thus taking into account visitors' previous ideas and interests. Also, science centres and museums impact at a local scale as they can become spaces that encourage local development and urban regeneration.

Many experiences around the globe, including in low- and middle-income countries, show that the impact and success of science centres and museums lie in their commitment to develop thoughtful programmes and activities that are community-driven or oriented. Therefore, achieving active and healthy science centres and museums is not really about huge financial investments – it is primarily about the people.

'The Value of Science Centres and Museums – especially in low- and middle-income countries' tries to help policy and decision-makers to look through the peephole of the wonder and potential of planning and making science centres and museums. It is hoped that this guide will encourage many more such centres to take root in more low- and middle-income countries, especially those where no such centre currently exists.

FAQs for policy- and decision-makers

Aren't science centres and museums spaces just for fun?

Although science centres and museums can offer fun programmes, there is worldwide scientific agreement that learning processes occur throughout our lives by participating in a wide range of leisure activities. Therefore, it is important to develop out-of-school policies that encourage science, technology and mathematics learning.

What size should a building be to be suitable for a science centre or museum?

The impact of the science centre or museum will largely depend on the quality of the offered experiences and, therefore, there is no need to provide or build a large building. A science centre could easily begin in a single room (within a university, for example).

How much does it cost to open a science centre or museum?

Although funding and support are vital for the science centre's sustainability, science centres and museums do not need great buildings nor expensive "ready-to-use" exhibitions but a dedicated team.

Do all science centres have a permanent exhibition?

No. Some science centres have only temporary exhibitions. Although most science centres do have some kind of exhibition, it is not mandatory. Science, technology and mathematics learning programmes and activities – without an exhibition space – can make effective science centres.

Should the science centre address all science topics?

No. Science centres can have main topics or disciplines according to their necessities and demands. What background should workers in a science centre and museum have? Ideally, an interdisciplinary team with specialists from science education, science communication, exhibitions design and management.

How many fixed-term positions will be needed to manage a science centre or museum?

It depends on each science centre and museum. However, it is important to have in mind that more visitors require larger teams.

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