Early Virtual Science Museums: When the technology is not mature

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This paper discusses three case studies of early science museum-related websites in the 1990s and early 2000s, when web technology was still relatively new and evolving. The Virtual Museum of Computing (VMoC) was a completely virtual museum, originally produced in 1995 as part of the Virtual Library museums pages (VLmp), an international online museum directory within the WWW Virtual Library, adopted by the International Council of Museums (ICOM). The Science Museum in London was one of the first museums in the United Kingdom to have its own web server. The museum hosted an early meeting on web service provision by and for museums, concurrently with an exhibition on the *Information Superhighway* at the museum in 1995. *Exhiblets* were launched online in 1998. Ingenious was a multi-site digital collections transformation project, launched as a website in 2003. Virtual Leonardo and Leonardo's Ideal City were two experiments conducted by the digital team of the Science and Technology Museum of Milan, between 1999 and 2001. The experiment consisted of the creation of a shared online 3D world, namely a reconstruction of the real museum in the first case and a completely imaginary world in the second case. This paper describes the above three case studies from the early World Wide Web and then draws some conclusions, from first-hand experience of developments at the time. We cover both the advantages and the challenges encountered by the various projects and illustrate why they did not necessarily become established, despite promising early results.

Keywords: virtual museum; science museum; World Wide Web; case study; internet history

Introduction

This paper discusses three case studies of early science museum-related websites in the mid to late 1990s and the early 2000s.

The *Virtual Museum of Computing* (VMoC) was a completely virtual museum, originally produced in 1995 as part of the *Virtual Library museums pages* (VLmp), an international online museum directory within the WWW Virtual Library, adopted by the International Council of Museums (ICOM). This experiment demonstrated the speed with which a virtual museum could be established (Bowen, 2000). It included virtual galleries, most notably on the computing pioneer Alan Turing (1912–1954). by his biographer Andrew Hodges. The virtual museum was mirrored around the world as part of the VLmp project.

The Science Museum in London was one of the first museums in the United Kingdom to have its own web server, second only to the Natural History Museum next to it (Bowen, 2010). The Science Museum hosted an early meeting on web service provision by and for museums, concurrently with an exhibition on the *Information Superhighway* at the museum in 1995 (Swade, 1995). *Exhiblets* were launched online in 1998 and they were considered the first virtual exhibition on the museum website that was not connected to a physical space or exhibition at the museum. Exhiblets were a low-technology enhancement to the website and were intended to be widely accessible for the public and school students. *Ingenious* was a multi-site digital collections transformation project, launched as a website in 2003. It made publicly accessible 30,000 digitized images together with related records sourced from the museum, the Science and Society Picture Library, and other related museums, with topical stories informed by the Exhiblets development and toolkits for users to build on their experience, by tagging and sharing object images.

Virtual Leonardo and *Leonardo's Ideal City* were two experiments conducted by the digital team of the Science and Technology Museum of Milan, between 1999 and 2001. The experiment consisted of the creation of a shared online 3D world, namely a reconstruction of the real museum in the first case and a completely imaginary world in the second case. The projects were based on an innovative platform developed by the Polytechnic University of Milan working on VRML, Java, and Java3D. Although there were technological issues, the platform offered many advanced features, such as: virtual guided tours, actionable machines, interaction between avatars, automated avatars, etc., well before Second Life.

This paper describes the above three case studies from the early World Wide Web and then draws some general conclusions, from first-hand experience of developments at the time. We cover both the advantages and the challenges encountered by the various projects and illustrate why they did not necessarily become established, despite promising early results. At that time, web information provision was relatively simplistic, although changing fast. We are now at a new expansion point in the web with the metaverse and Web3. We consider some possible future advances with the hindsight of early web experiences.

By way of background in a more general framework, we draw the reader's attention to several more discursive papers on museum website development and museum informatics in general (Bearman & Trant, 2018; Laws, 2015; Marty, 2007; Marty, 2018). The case studies have been undertaken within a framework suggested by Ebneyamini, & Sadeghi Moghadam (2018). The purpose is practice-oriented, and the paper provides first-hand self-reported qualitative descriptions of multiple case studies by the original participants, at a time when web technology was still immature and changing relatively rapidly. We hope that the experiences described will be useful as input for other independent researchers in more general surveys.

The Virtual Museum of Computing

This section discusses an early virtual museum, established in the 1990s when museum resources online were still a novelty (Bowen 1995a). The *Virtual Museum of Computing* (VMoC) was a completely virtual museum that formed an eclectic collection of links and online resources concerning the history of computers and computer science (IEEE,1996; Leslie, 2001). It includes links to other related museums, both real and virtual, around the world, as well as having its own virtual galleries of information. A particular feature was the early computing pioneer Alan Turing, among others, with information created by Andrew Hodges, Turing's definitive biographer (Bowen et al., 2005).

The VMoC virtual museum was founded by Jonathan Bowen at the University of Oxford on 1 June 1995 and was announced the following day on the *comp.infosystems.www.announce* online newsgroup, now part of Google Groups (Bowen, 1995b). It was originally hosted on the Oxford University Computing Laboratory web server in the United Kingdom (Bowen 2010). It formed part of the *Virtual Library museums pages* (VLmp), itself a section of the Virtual Library established by Tim Berners-Lee to form a directory of the web before good search engines were available (Gaia et al. 2020; Marty et al., 2021). VLmp and VMoC were later supported by the International Council of Museums (ICOM). They were subsequently hosted at the University of Reading (see Figure 1) and then by Museophile Limited on a web server at London South Bank University. The VMoC resource was mirrored around the world as part of VLmp and both are still available as a wiki on the *MuseumsWiki*, hosted on Wikia, now rebranded as Fandom (MuseumsWiki, n.d.).

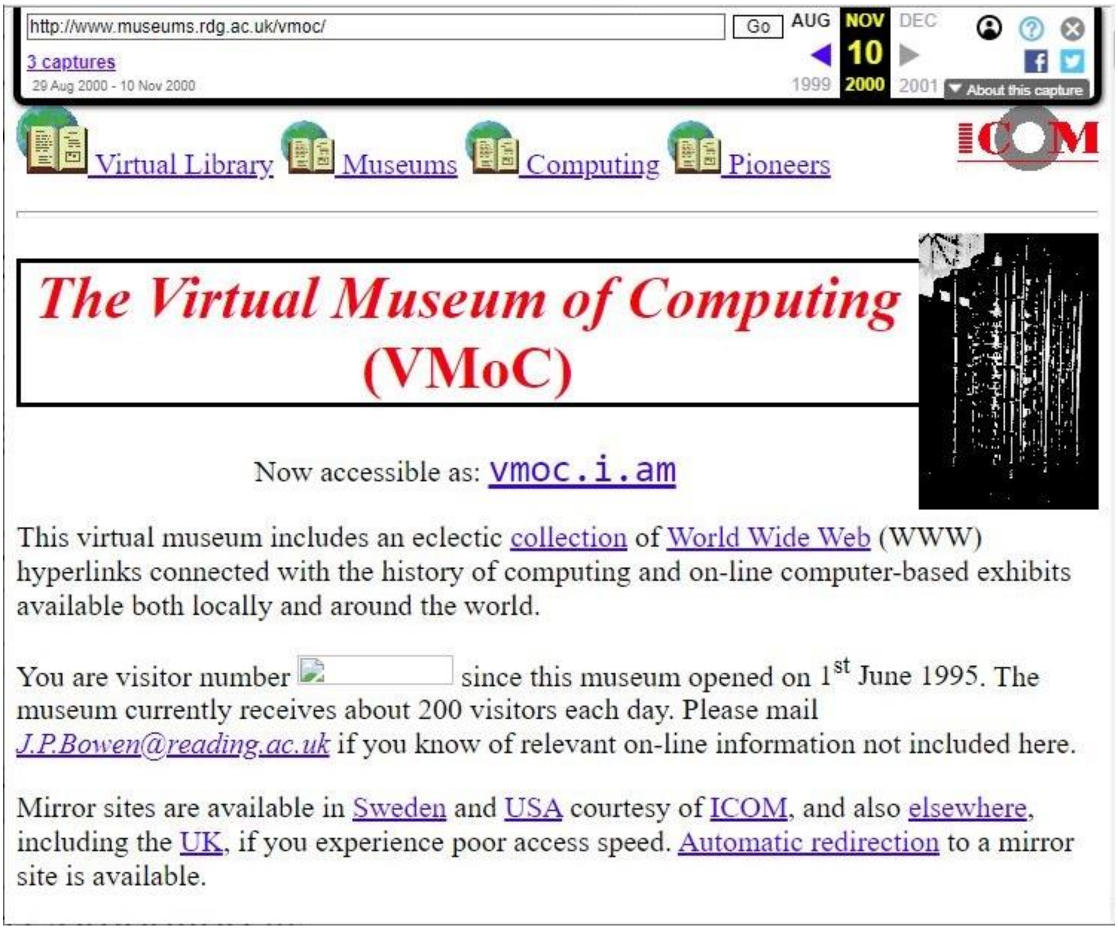


Figure 1. Home page of the Virtual Museum of Computing at the University of Reading, UK. Internet Archive, 10 November 2000. https://web.archive.org/web/20001110125900/http://www.museums.rdg.ac.uk/vmoc/

During the 1990s, VMoC received a significant amount of recognition online. For example, it was:

- Reviewed by *Lycos* as a top 5% website.
- Recommended by the Discovery Channel in *A History of the Internet*, 1995.
- *Planet Science* Site of the Day, 21 October 1996.
- Awarded Best Site from *Bookmark Central*, January 1998.
- Reviewed by *Science NetLinks*, May 1998.

- A 5-star site under Computing Milieux from *Anbar Electronic Intelligence*, January 1999.
- Site of the Day in *RedOrbit*.

Most of these have now disappeared from the web with the speed of change online. However, the resource has been widely cited in books (Google Books, n.d.) and academic publications (Google Scholar, n.d.). It was originally created to provide information on computer history and act as an educational resource (Lee, 2004; Farr et al., 2016). VMoC also hosted information on events related to computing history (Numerico & Bowen, 2005). The resource has been described internationally, including in different languages (Максимова, 2012).

Overall, VMoC provided an important focus for computer history in the early days of the web, especially during the mid to late 1990s. At that time, it was possible for an individual with the appropriate resources, especially if at a university with web servers and good network connections, to create web-based resources that could quickly become popular due to the paucity of information available online. However, even by the end of the 1990s, maintenance of museum-related websites was becoming a significant issue, with effort needed to keep such sites looking fresh and keeping them up to date (Bowen, 1999).

Nowadays any museum or individual can easily have their own website and create online material as they wish, with software to support this. Since the publication of Bowen et al. (2005), other online resources such as Wikipedia have enabled individuals to create information on a very wide range of topics, including the history of computing and individual museums (Bowen & Angus, 2006). Search engines, especially Google, allow users to find information very quickly, so directory-based resources such as VMoC, VLmp, and the entire Virtual Library, have essentially become redundant.

Although VMoC is now hosted on a wiki site that can be edited by anyone, it is far more productive to use Wikipedia for supplying information on virtually any subject, including the history of computing. Attempts have been made by museums to create wikis (Bowen 2008; Liu & Bowen, 2011), but the issue is typically that achieving a critical mass of users over the long term is very difficult. Additionally, Wikipedia has enough critical mass of editors to ensure that errors are corrected (eventually at least) and that its long-term future is secure. The associated Wikimedia Commons website allows images to be added with relevant metadata. Thus, as a recommendation, this is where it is better to devote time to creating content originally provided by VMoC and similar resources.

While Wikipedia is appropriate for indexing at the level of individual museums, some important museum collections, and even some significant individual objects in museums, it is not appropriate for a more universal indexing of museum collections and objects. The rules of Wikipedia on notability, secondary sources, etc., would not allow this. A project to do this would require very significant organizational and financial resources. Europeana (https://www.europeana.eu) has made some efforts in this regard within Europe, funded by the European Union. A more international effort would require an organization like the International Council of Museums (ICOM), but the resources needed are outside ICOM's means without additional funding support. An organization like Google, which has undertaken projects to index books (https://books.google.com) and academic publications (https://scholar.google.com) for example, has not had the motivation to index museum collections and objects in a similar way, although it has initiated a more limited project on arts and culture (https://artsandculture.google.com). Currently, there is no prospect of such a universal museum collections project known to the authors, but it would be an interesting and welcome development for the future.

The Science Museum, London

The Science Museum based in South Kensington, London, was established in 1857 with founding collections sourced largely from the Great Exhibition of 1851. It became administratively part of a broader organization of the National Museum of Science and Industry (NMSI) from the 1920s, comprising The Science Museum in London, the National Science and Media Museum in Bradford (formerly known as the National Museum of Photography, Film and Television), and the National Railway Museum in York. Now known as the Science Museum Group, it comprises the NMSI museums, and since 2012, The Museum of Science and Industry in Manchester, The Science Museum in Swindon, and The National Railway Museum in County Durham.

Of the NMSI museums, The Science Museum undertook significant web-based projects to enable access to science learning and object-based resources (Borda & Bud, 2003; Borda & Beler, 2003; Ellis & Borda, 2004) and was among the first science museums to push the boundaries of going beyond organizational structure in its website arrangement to focus on a range of visitors' needs who were becoming more aware of the web (Sabin 1997; Streten, 2000; Bowen et al., 2005). The Science Museum website was pioneering in this development and gained early momentum in the mid-1990s (Bowen, 2010). Virtual visitors were accessing virtual galleries as soon as they became available in April 1995 with over a quarter million visitors in the first year and incrementally higher numbers recorded at the start of 1998 (Booth 1999). Notably between 1997 and 1999, the Science Museum began a review of its Internet presence and looked to provide a more interactive and audience-friendly web experience, including multiple types of web content and information structures to support different audiences (Streten, 2000). One of the outcomes in the latter half of 1998 was the appearance of *Exhiblets* (see Figure 2), the first exclusively virtual exhibition that did not reference a physical space or exhibition in the actual museum space (see Figures 2–6). The name *Exhiblet* is derived from a combination of the two terms “exhibition” and “Java Applet”. It represented a set of online information resources that focused on a specific object or collection to explain events, discoveries, and personalities (Borda et al., 1999; Ellis and Borda, 2004).

Figure 2. Exhiblets header icon on Science Museum home page. Internet Archive (www.ScienceMuseum.org.uk), 9 October 1999. https://web.archive.org/web/19991009181416/http://www.sciencemuseum.org.uk/welcome.html

Each Exhiblet comprised of a narrative, object list, and bibliography. The original six topics of these virtual exhibitions covered Marie Curie, Portsmouth blockmaking machinery, railway posters, barometers, atomic physics, and typewriters. These topics represented collections across the individual NMSI sites (Borda et al., 1999; Ellis & Borda, 2004). In the first month of the launch, Exhiblets accounted for nearly 10% of all Science Museum website hits (NMSI, 2000).

In the conception of Exhiblets, it was intended that their design should support several functions, including acting as online resources for some of the thousands of collections-related enquiries the Museum received each year (Ellis & Borda, 2004). The resources were a form of proactive approach to enquiries in popular areas, such as learning more about Nobel Prize physicist and chemist, *Marie Curie* (see Figure 3), and to highlight collections within a historical context. The success of Exhiblets can, perhaps, be gleaned from the web statistics of December 1999, which reveal that "Marie Curie" was a top search phrase that led visitors to the Science Museum website, only exceeded by the term "science museum".

An especially novel aspect at the time was that Exhiblets drew on information held in various forms and subject domains across the Science Museum, but they were "born digital" features (Parry, 2010), linking audiences to collections and stories. Sometimes they referenced more contemporary social events, such as Black History Month in October 2000, which provided an opportunity to raise awareness of the African-American inventor, Garrett Morgan (see Figure 3).

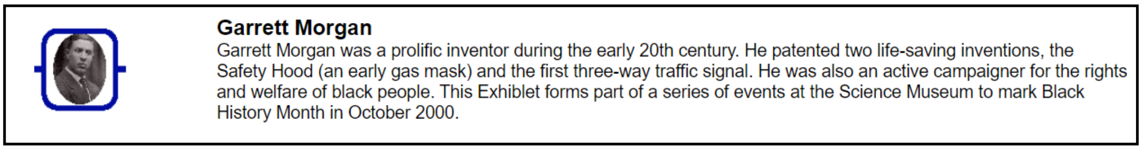


Figure 3. Snapshot of Exhiblet header for Garrett Morgan. Internet Archive (www.ScienceMuseum.org.uk), 6 January 2001. https://web.archive.org/web/20010106043100/http://www.sciencemuseum.org.uk/collections/exhiblets/f.htm#f

Comprising information drawn from the Museum collections, the Museum's Library and Archive and curatorial publications, Exhiblets depended on information being made accessible at the item and collection level, and placed in a narrative context (Dempsey, 2000). For example, an Exhiblet on the *Portsmouth Blockmaking Machinery* (see Figure 4) provided a glimpse of the evolution of mass production using metal machine tools. Descriptions and images of the objects held at the Science Museum and in other UK museums were part of the narrative about the beginnings of the industrial revolution. The holdings of the Science Museum Library were referenced as well as archival sources, such as letters between the inventors and manufacturers designing and using the machinery.

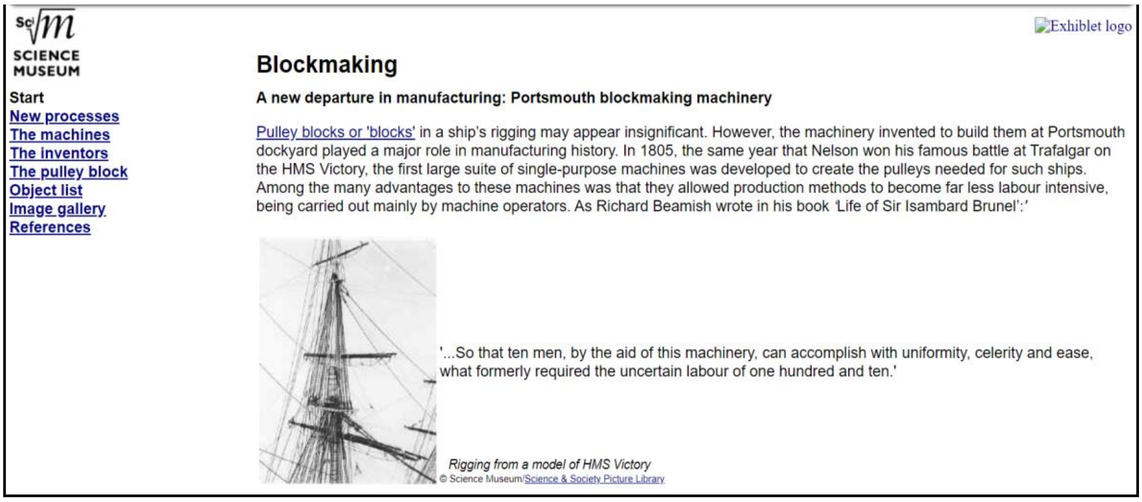
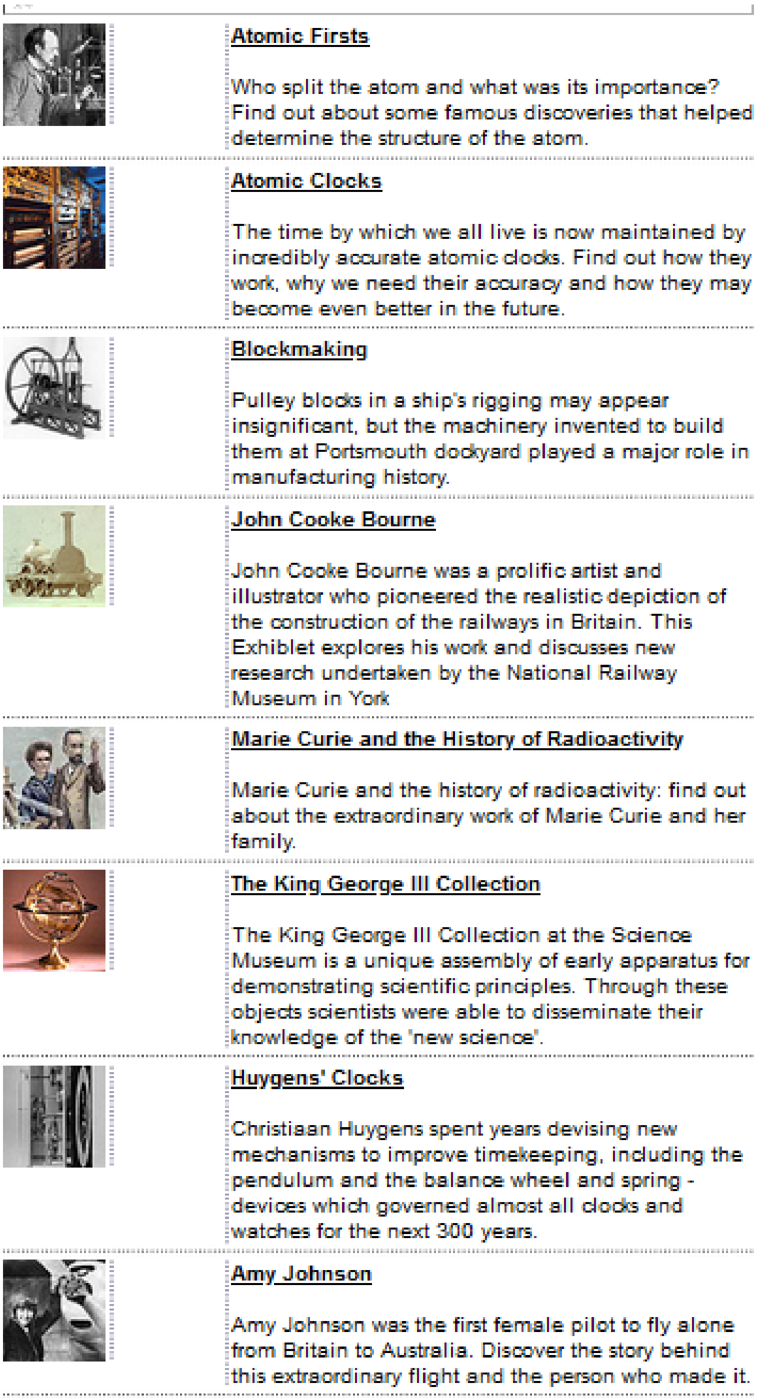


Figure 4. Snapshot of the Portsmouth Blockmaking Machinery from the Science Museum website. Internet Archive (www.ScienceMuseum.org.uk), 12 February 2001, https://web.archive.org/web/20010212023918/http://www.sciencemuseum.org.uk/collections/exhiblets/block/start.htm

Exhiblets were a relatively low-tech addition to the website and were intended to be easily viewed by different browsers and printed out as a resource by the public and particularly by educators and school students (Ellis & Borda, 2004). This complemented the availability of activity sheets that the Education group at the Museum had placed online for printing and downloading for teachers and schools. Fourteen Exhiblets were produced by 2002 (see Figure 5) and were appearing on the website under “Collections and Research” as well as “Exhibitions Online”.



Atomic Firsts

Who split the atom and what was its importance? Find out about some famous discoveries that helped determine the structure of the atom.

Atomic Clocks

The time by which we all live is now maintained by incredibly accurate atomic clocks. Find out how they work, why we need their accuracy and how they may become even better in the future.

Blockmaking

Pulley blocks in a ship's rigging may appear insignificant, but the machinery invented to build them at Portsmouth dockyard played a major role in manufacturing history.

John Cooke Bourne

John Cooke Bourne was a prolific artist and illustrator who pioneered the realistic depiction of the construction of the railways in Britain. This Exhiblet explores his work and discusses new research undertaken by the National Railway Museum in York

Marie Curie and the History of Radioactivity

Marie Curie and the history of radioactivity: find out about the extraordinary work of Marie Curie and her family.

The King George III Collection

The King George III Collection at the Science Museum is a unique assembly of early apparatus for demonstrating scientific principles. Through these objects scientists were able to disseminate their knowledge of the 'new science'.

Huygens' Clocks

Christiaan Huygens spent years devising new mechanisms to improve timekeeping, including the pendulum and the balance wheel and spring - devices which governed almost all clocks and watches for the next 300 years.

Amy Johnson

Amy Johnson was the first female pilot to fly alone from Britain to Australia. Discover the story behind this extraordinary flight and the person who made it.

Figure 5. Snapshot of Exhiblet topics from the Science Museum website. Internet Archive (www.ScienceMuseum.org.uk), 6 June 2002, .

Exhiblets, however, were only one entry point on the website into the Science Museum collections and they served as a springboard for other applications (Ellis & Borda, 2004; Bowen et al., 2005). More interactive applications were developed around iconic objects and exhibitions in the Science Museum galleries, starting even before the use of the web (Boiano et al., 2022), and these would overtake the Exhiblet format. One of the earliest features to use a form of virtual reality (VR), for instance, was the online exhibition for the Apollo 10 Command Module, which incorporated an activity entitled "Design your own rocket" (Ellis & Borda, 2004).

The growing proliferation of such online resources and the potential standardization of these for motivational learning and virtual classroom experiences were a focus of the nascent Online Museum Educators network, of which a chapter of six Online Museum Educators was based at the Science Museum by the early 2000s (Bazley 2001). Ongoing evaluations of accessibility and usability of museum websites were also becoming part of professional practice (Marty & Twidale 2004).

The Ingenious Project

Museum websites can reach audiences around the world, and with digital technology can capture and store their collections online (Parry, 2010). This was part of the ambition of *Ingenious*, a UK lottery-funded NOF-Digi programme (Nicholson & MacGregor, 2003), which represented at the time the largest object-based Internet project and "microsite" undertaken by the Science Museum in partnership with its sister sites under NMSI. Launched in the Spring of 2004, the aim of Ingenious was to provide public access to 30,000 digitized images and accompanying records, 10,000 library records, and 10,000 object records from the Science Museum, including material in the Science and Society Picture Library, the National Railway Museum in York, and the National Museum of Photography, Film and Television (now known as the National Science Museum of Media) in Bradford. In addition, this material was contextualized by several hundred pages containing about 40 topical stories aimed at lifelong learners (Borda& Bud, 2003; Borda & Beler, 2003). See Figure 6.

Like Exhiblets, these topics used primary material "to weave connections between the people, innovations and ideas that have changed our lives and the way we see the world, from the industrial revolution to the present day" (extracted from the Vision statement). Through these "Science and Culture" connections, users had the opportunity to find meaning for themselves, by being presented with tools to create and contribute to subject-driven debates and personalized content (Borda & Bud, 2003). Web-based stories could resemble the semi-linear exploration of the museum visit and capture some of its sense of self-guided discovery and, even, personal construction of meaning and the story (Borda & Bud, 2003, p. 27). See Figures 6 and 7.

Figure 6. Screenshot from www.Ingenious.org.uk website – homepage with Flash banner for "READ" activity (accessed March 2016). Note that the Flash banner function was not preserved in the archived versions of the site.

Figure 7. Screenshot from www.Ingenious.org.uk website – from the "READ" topic browser for Science and Culture with relational subject links. The National Archives, UK. https://webarchive.nationalarchives.gov.uk/ukgwa/20170405142426/http://www.ingenious.org.uk/Read/ (accessed 5 September 2023).

Critically, Ingenious met a key funder's requirement in providing one of the largest online databases of collection images and records free at the point of access under the NOF-Digi programme. Behind the scenes, making this access possible required the need to effectively manage, standardize and integrate data sourced from five catalogue databases in use at three distributed museum sites, including the Science Museum library and Science & Society Picture Library, for delivery to a web platform

(Borda & Beler, 2003). The main cataloguing and content management system for object records was the Multi MIMSY 2000™ system (now Mimsy XG), which was in use by the three museums, and had a web publishing feature that was configured for the project.

The uniqueness of the website was not only to make this rich quantity of material accessible but also to contextualize it through intelligent display, searching (resource discovery), and relational linking. To accomplish this, a data hub was designed to act as a collection point for data harvested from the various systems. The primary purpose of the database was to feed the web content management system (CMS) with metadata and digital files. It was a separate entity from the web CMS due to differences in functionality and purpose, namely to "normalize" data, generate automatic fields and tags, and to manage the data through specific tools. Significantly, this digital media hub could potentially support future digital resource projects by providing a variety of benefits (Borda & Beler, 2003):

- conform to future standards (e.g., Dublin Core);
- repurposable – data to be held in an XML wrapper, which allows it to be used in a variety of applications: "Create once and use many";
- customizable according to needs;
- ability to share data across organizations and between institutions;
- creating different channels.

Ingenious, also termed a "knowledge" site in its description, was designed with relational linking across record types (e.g., object, image, library record) – a central functionality supported by standardized Dublin Core subject item and collection level categories. A dedicated group of subject experts from across the NMSI museums, the Science Museum Library, and the Science and Society Picture Library, agreed on two levels of breadth subjects, which categorized images, objects, library records, and stories, and on which users could search or browse. The broad subject level 1 categories were: Entertainment and Media, Medicine and Health, Natural World, Science and Technology, Society and Wars, Trade and Industry, and Transport. Broad 2-level sub-categories were mapped to these to produce a schema (See Table 1).

Table 1. Subjects: Broad 1 and Broad 2 categories (shortened version).

DC:Subject.Broad1	**DC:Subject.Broad2**
Entertainment & Media	Cinematography & Film
Entertainment & Media	Photography
Entertainment & Media	Television
Entertainment & Media	Visual Arts
Medicine & Health	Anaesthesiology
Medicine & Health	Anatomy & Pathology
Medicine & Health	Classical & Medieval Medicine
Medicine & Health	Clinical Diagnosis
Medicine & Health	Dentistry
Medicine & Health	Nursing & Hospital Care
Medicine & Health	Obstetrics, Gynaecology & Contraception
Medicine & Health	Orthopaedics
Medicine & Health	Psychology, Psychiatry & Anthropometry
Medicine & Health	Public Health & Hygiene
Medicine & Health	Radio Medicine & Body Imaging
Medicine & Health	Surgery
Natural World	Astronomy
Natural World	Environmental Science & Technology
Natural World	Geology & Geophysics
Natural World	Meteorology
Natural World	Natural History

Natural World	Oceanography
Science & Technology	Biology & Biotechnology
Science & Technology	Chemistry
Science & Technology	Computing & Data Processing
Science & Technology	Mathematics
Science & Technology	Physics
Science & Technology	Space Technology & Rocketry
Science & Technology	Telecommunications
Science & Technology	Weighing & Measuring
Society & Wars	Domestic Life & Household Management
Society & Wars	Ethnography, Customs & Beliefs
Society & Wars	Food & Drink
Society & Wars	People & Personal Life
Society & Wars	Sports & Pastimes
Society & Wars	Wars & Wartime
Trade & Industry	Agriculture & Fishing
Trade & Industry	Building Construction & Architecture
Trade & Industry	Fuel & Power
Trade & Industry	Glass Technology & Ceramics
Trade & Industry	Hand & Machine Tools
Trade & Industry	Mining & Ore Dressing
Trade & Industry	Plastics
Trade & Industry	Textile Industry
Transport	Aeronautics
Transport	Navigation
Transport	Railways
Transport	Road Transport
Transport	Water Transport

This data schema was used to code object records, images, and textual resources at the item level. It featured as the underlying structure to the browse and search functions, so users could search broad themes or refine their search and locate related materials (See Figures 8 and 9).

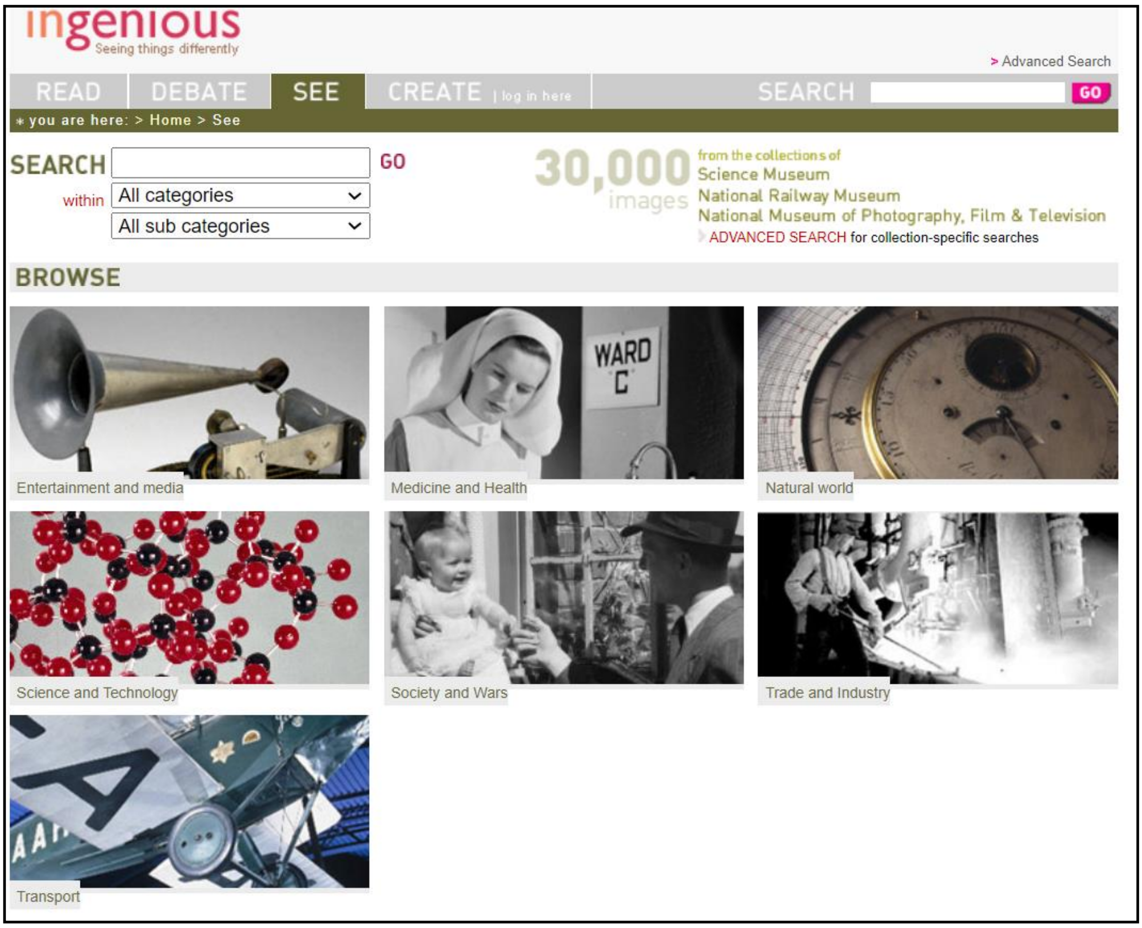


Figure 8. Screenshot of the search function and main browse categories (Broad 1 subject terms) with subcategories (Broad 2 subject terms) search field. Ingenious website from the "SEE" page. The National Archives, UK (www.Ingenious.org.uk). https://webarchive.nationalarchives.gov.uk/ukgwa/20170405142522/http://www.ingenious.org.uk/See/ (accessed 5 September 2023).

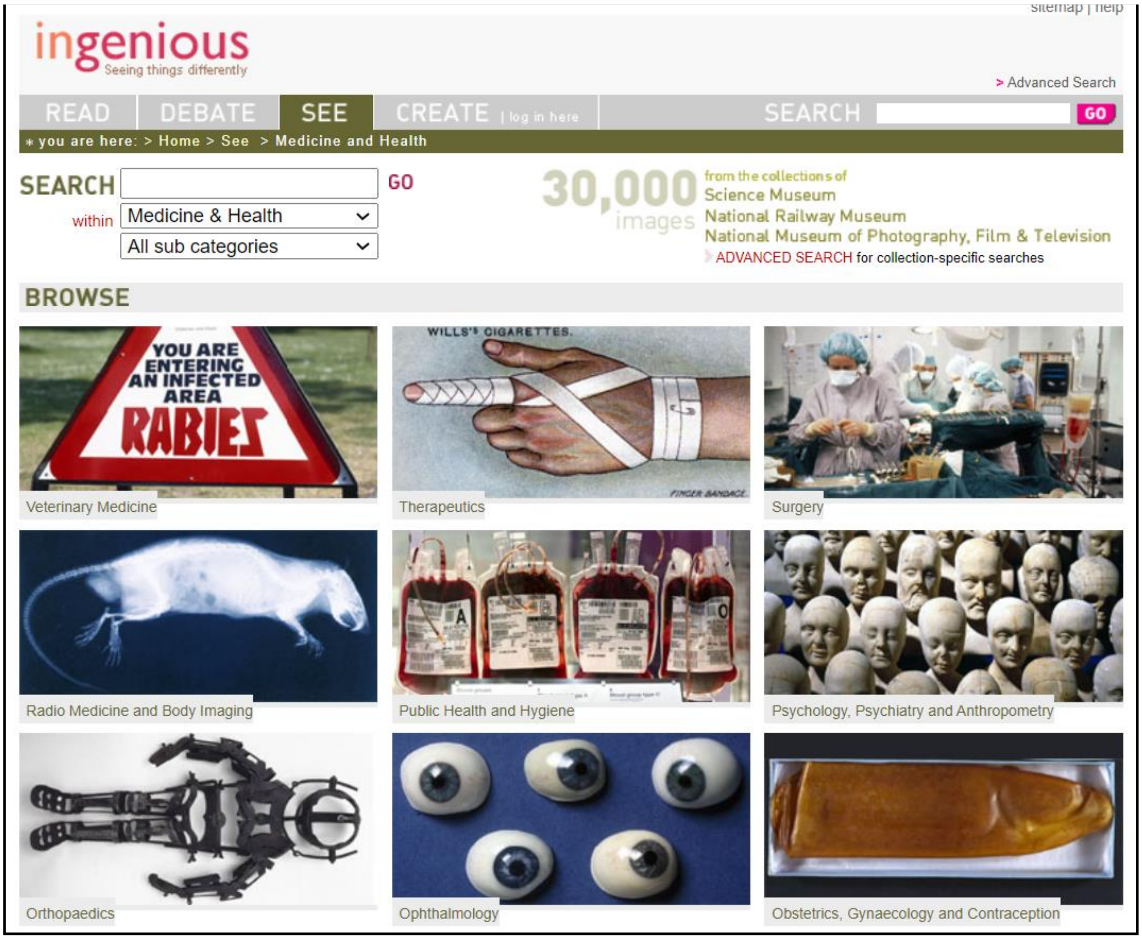


Figure 9. Screenshot of the Medicine and Health browse categories (Broad2 subject terms) of the Ingenious website from the “SEE” page. The National Archives, UK (www.Ingenious.org.uk). https://webarchive.nationalarchives.gov.uk/ukgwa/20170405164817/http://www.ingenious.org.uk/See/Medicineandhealth/ (accessed 5 September 2023).

The creation of a personalized environment was possibly the most progressive aim of Ingenious. For example, by providing the user with customizable tools to create their own stories (see Figure 10), the Science Museum enabled the growth of a community. Topics also defined what could exist in a community, as well as providing a form of social ontology (Dempsey, 2000; Beler et al., 2004). The idea of the participatory museum (Simon, 2010) was being seeded in the process, alongside the need to address the interest of museum visitors and communities through innovative online tools.

Figure 10. Screenshot from the Ingenious CREATE home page. The National Archives, UK (www.Ingenious.org.uk).https://webarchive.nationalarchives.gov.uk/ukgwa/20170405142449/http://www.ingenious.org.uk/Create/ (accessed 5 September 2023).

There were four customizable tools available on the Ingenious site, mainly to users who registered an email address, which allowed saving and sharing. The tools were: **My links** | **My search** | **My 'Lightbox'** | **My 'Gallery'**. If the user registered on the site, they could allow others to view and share their "personal" space and could send any of their personal resources via email. Additionally, registered users had access to the debate forums and could contribute to conversational topics such as the human genome project and other contemporary issues (Borda & Beler, 2003).

The large image-based resources of Ingenious were key to supporting the personalized tools, such as “My Lightbox” where users could view saved images and “My Gallery” where users could transfer selected images from their lightbox and create a mini gallery in the form of a slide show with their own annotations. This creative process provided an individualized means of making learning resources of direct significance to the user. In this way, the Ingenious tools intended to extend the functions of the online museum so that it moved beyond a catalogue of information to a wider exchange. Before Twitter, Instagram, and Facebook, the changing scope of personalization advanced by Ingenious took into consideration that information-seeking and image capture can be disseminated, shared, and extended by others’ contributions, resources and personal knowledge base – a case of building “my community”, rather than simply “my information” (Rheingold, 2000).

The result of a unique collaboration across curatorial, collections, exhibition, education, web and IT stakeholders of several museum organizations, the Ingenious microsite received 368,000 visitors in its launch year in 2004 and won awards for “best new launch” by the Online Publishers Association and selected as *Webby Worthy* by the International Academy of Digital Arts and Sciences (NMSI 2005). Alongside the virtual presence of the site, an *Ingenious* gallery in the Science Museum was opened in 2004 with an object-rich exhibition about energy aimed at families and incorporated visitor responses to some of the Museum’s less explanatory exhibits (NMSI 2005).

Different approaches to the provision of content personalization for online audiences have subsequently been evolving on the Science Museum Group’s web pages over time (Filippini-Fantoni et al 2009), as well as the advancing integration of interactive online experiences into organizational digital strategies (Stack 2016). However, the longevity of the Ingenious site, archived in April 2017 by The National

Archives in the UK (and still accessible), may be due in part to its curated structure and integration of rich object data and learning resources which represent key digital collections across the Science Museum Group institutions and not least, the iconic objects which continue to be associated with scientific exploration and discovery. Not unrelated, the Ingenious site was mentioned as a visitor resource during the COVID-19 pandemic which provided virtual access to major collections whilst the museums of the Science Museum Group were closed (Bud 2020).

Virtual Leonardo and Leonardo's Ideal City

This section discusses two pioneering museum projects based on the WebTalk technology, a platform that was developed at the Milan Polytechnic during the years approximately 1998–2006 (Barbieri et al., 2006; Barchetti et al., 2006). The WebTalk platform was a collaborative 3D online environment, able to make users from all over the world see and interact with each other, through both a chatting system and also the possibility of exploring 3D environments and activating virtual objects.

The WebTalk technology was very promising, but it was only at its prototyping stage in 1998. Giuliano Gaia, at the time working as the webmaster for the Museum of Science and Technology in Milan, approached Professor Paolo Paolini, mentor of the WebTalk project, and offered the Milan Science Museum website as a testing ground for the technology and a proof of concept for a 3D collaborative virtual museum.

At the time, the Milan Science Museum website was one of the most popular museum websites in Italy, and its digital department, run by Giuliano Gaia and Stefania Boiano, was known for its willingness to "play" with technology in new and intriguing ways. For example, it hosted the first ADSL (Asymmetric Digital Subscriber Line) public lab in Italy for schools and visitors in 1998, created one of the first online artificial intelligence (AI) chatbots in 2002 (Gaia et al., 2019) and in 2000 reactivated the web server and web browser on the original NeXT machine (on lease from CERN) on which Tim Berners-Lee programmed the early World Wide Web around 1990.

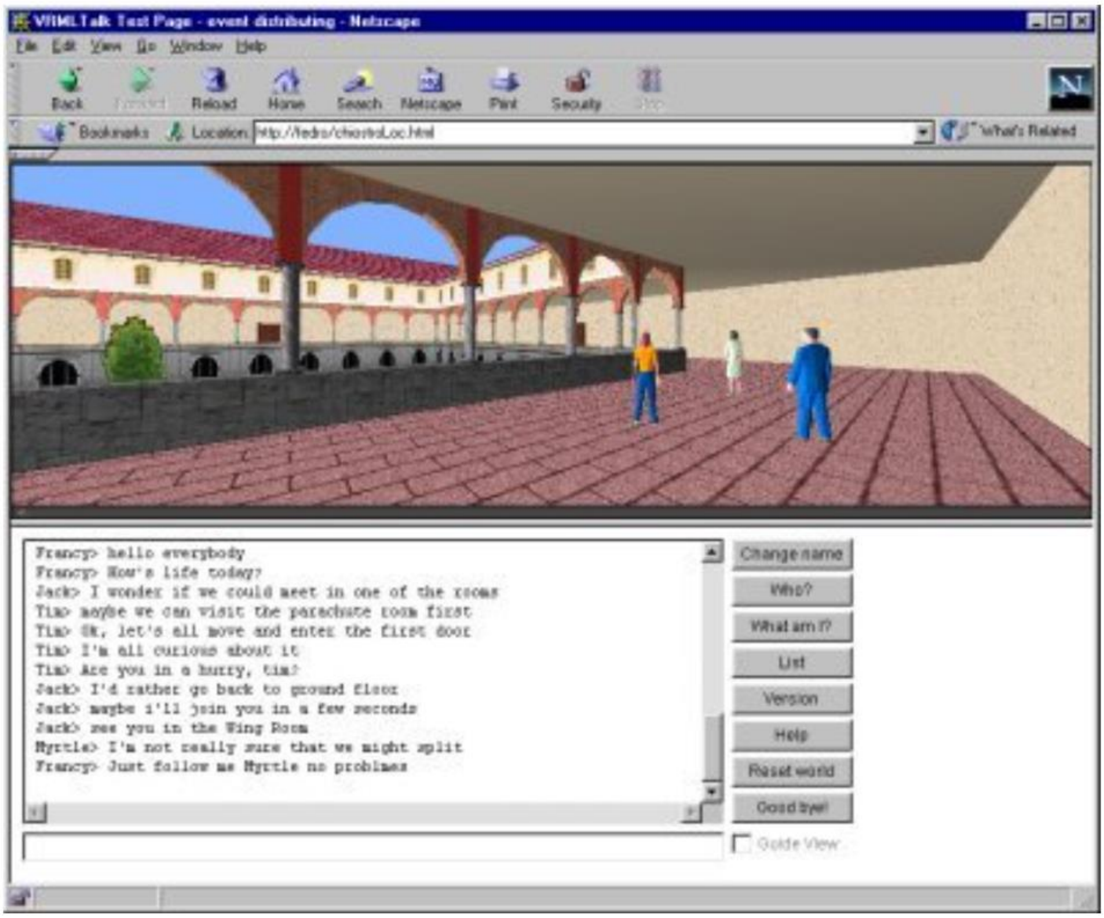


Figure 11. Screenshot from Virtual Leonardo.

Therefore, the usage of the Milan Science Museum website as a testing ground offered the advantage of bringing many users to the system and being open to failure, since the museum's digital department was known for its bold experimental approach.

The goals of the museum were:

1) to experiment 3D cooperative worlds as a new way to approach online visitors, for example organising virtual guided tours;

2) to strengthen the idea of the Science Museum website as a place for online experiments;

3) to exploit the appeal of Leonardo Da Vinci's machines to lure visitors into the new world.

The result of the project was Virtual Leonardo (Barbieri & Paolini, 2001a), an online 3D reconstruction of the two cloisters of the Milan Science Museum (see Figure 11), with animated Leonardo da Vinci's machines scattered around the virtual space (see Figure 12). Visitors could have their avatars walk and fly around the cloisters and rooms, chat with an avatar guide or with other visitors, and set in motion the machines. The tour guide avatars had the special power to force all users to see what they were seeing in that moment, to make the tours easier (Paolini et al., 2000).

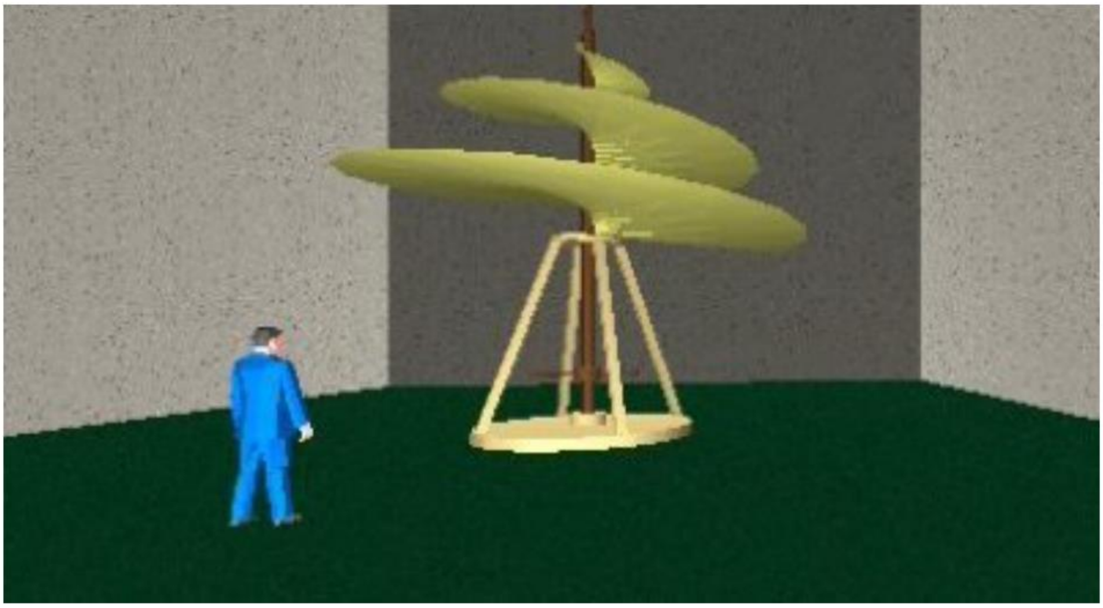


Figure 12. One of the da Vinci machines, operable by online visitors.

The system went online on 7 June 1999 and raised much interest, winning an Honorable Mention at the *Museums and the Web* Best of the Web awards in 2000 and being featured in the *New York Times*.

From a technological point of view, Virtual Leonardo consisted of a combination of VRML (Virtual Reality Modeling Language) technology, a markup language proposed in 1994 to create a standard for 3D visualization in the World Wide Web (Raggett, 1994) for the 3D environments and Java for the infrastructure allowing users to chat between themselves and to interact with the guides and the animated objects.

Unfortunately, the technology was still immature and not user-friendly. The user had to download and install a specific plug-in, Cosmo Player, to be able to visualize VRML and needed a good computer with a strong Internet connection to make the system work smoothly, something that was not common at the time. The result was that only 20% of the users were able to have a successful experience interacting with the system; an interesting insight was that the average connection time among successful users was nearly one hour, confirming that the experience was "sticky":

> "…76% of visitors tried to start the system without the appropriate hardware or software pre-requisites (even if clearly stated in the login html page of the system); 50% of users that successfully logged in had trouble in using it properly, 30% did not find other people with whom to collaborate. But when people understood the system and started collaborating with each other (20% of the connections) or with an available museum virtual guide, the average connection time to the virtual world was over 53 minutes, spent visiting the exhibition and learning." (Paolini et al., 2000, p. 3).

Users encountered three main types of problems:

(1) a high technical barrier (downloading and installing the plug-in and making it work);

(2) poor confidence with navigation within 3D environments;

(3)a poorly populated environment. When users logged into the environment, they found very few users or no users at all. (Paolini et al., 2000, p. 4).

To address these problems, a new version was designed and developed in 2001–2002 by the Polytechnic University of Milan with the Milan Science Museum. The new platform replaced the Cosmo Player VRML plugin, which had proved unreliable, difficult to install, and limiting in the interface, and was rewritten entirely in Java and Java3D. This meant that it was a browser-independent app. From a technical point of view, this guaranteed more flexibility and reliability, even if still required the user to install the Java 3D environment and to use a computer with a 3D accelerated card, to experience a good level of performance. An important technological threshold was therefore maintained in the system and prevented a more widespread adoption by average users.

Together with the launch of the new technology, a new virtual environment was designed and built, related not to the existing museum but to the ideal city (see Figures 13 and 14) imagined by Leonardo da Vinci during his Milanese years (Barbieri & Paolini, 2001b).

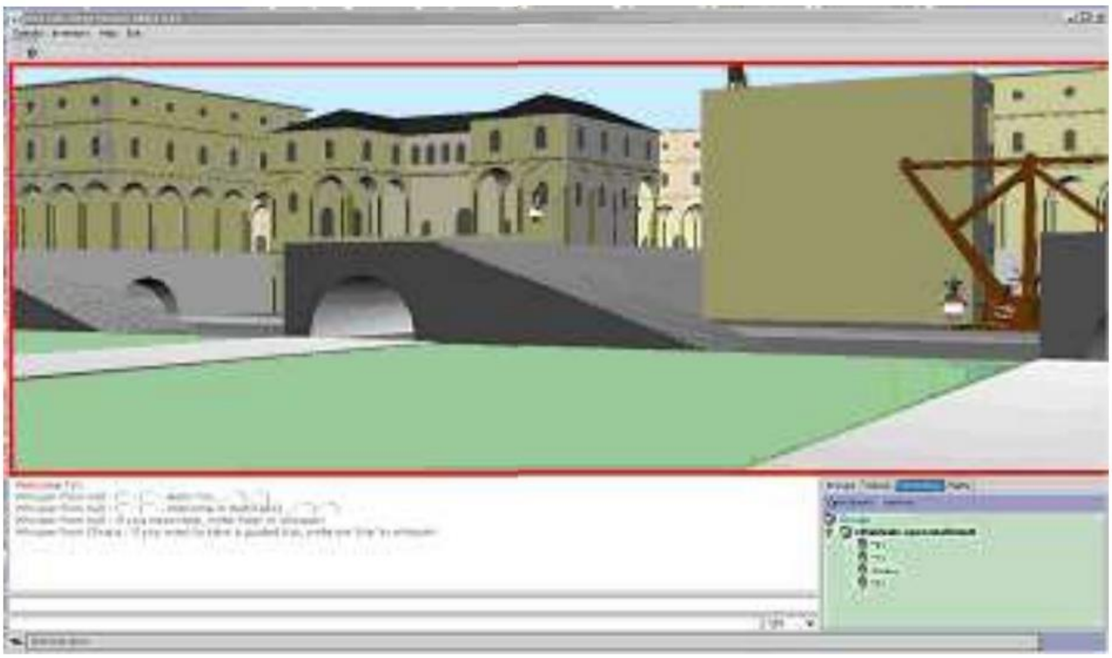


Figure 13. Screenshot of the ideal city project. Beneath the 3D navigation area, the chat window (bottom left) and the collaboration area (bottom right) allow users to communicate with each other and with virtual guides.

The virtual environment included not only Da Vinci’s machines but also artificial avatars operating them, to make the place more populated and to show first-time visitors what they could do in the environment.

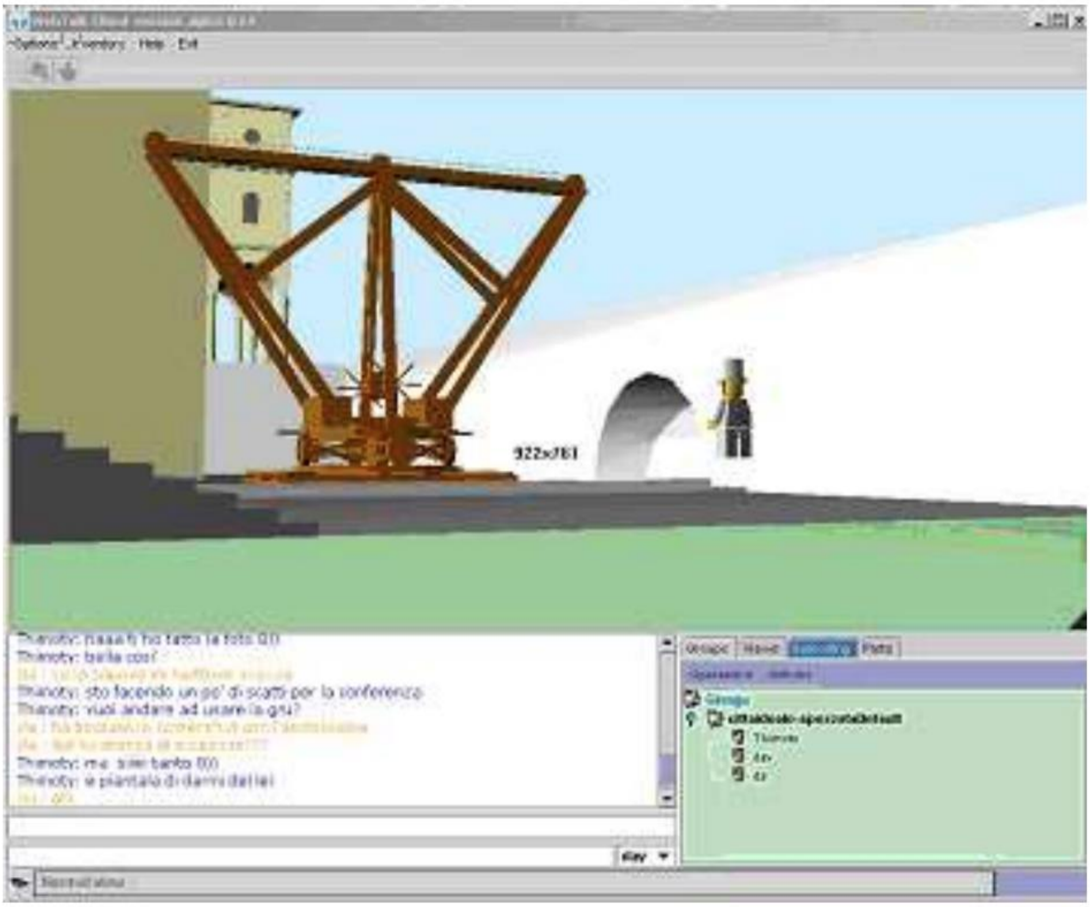


Figure 14. A screenshot from the ideal city project. A user is approaching an interactive machine and operating it. All other users are aware of his movements and his actions over this specific object.

The new system was built and presented at the international conference ICHIM 2001 but never officially launched online on the Milan Science Museum website. This was due to many reasons. There were political reasons: the new museum director, Fiorenzo

Galli, changed the museum’s priorities and digital innovation became less important. Moreover, Giuliano Gaia and Stefania Boiano left the Milan Science Museum at the end of 2002, de facto ending the collaboration between the Museum and the HIC laboratory of the Polytechnic Museum. Therefore, the Polytechnic adapted the Webtalk technology to build cooperative learning environments, abandoning the museum environment.

The abandonment of the 3D cooperative online museum, built years before the launch of Second Life in 2003, was certainly a missed opportunity. On the other hand, museums are not suitable environments for the development of new technologies, because they tend to lack the resources to bring prototypes to the product stage.

Still, both projects demonstrated that a cooperative virtual environment, where users can interact with each other and interact with exhibits, has a strong educational value and is, therefore, useful to pursue. Whether this must be done by building your own virtual environment, as the Milan Science Museum did, or by using an already existing environment, as some museums are doing with Minecraft (Charr, 2021), is still open for debate; both solutions have pros and cons. However, in the end, we believe that museums will be an important contributor to developments in the new metaverse (Giannini et al., 2022).

Reflections and Conclusions

This paper has discussed three case studies of early science museum-related websites in the 1990s and early 2000s. Here we reflect on the success and ultimate demise in the light of changing digital technology and environment for each of them.

The *Virtual Museum of Computing* (VMoC), established in 1995, is effectively now a historical digital artefact itself. The need for such a resource has been overtaken by the development of fast and reliable search engines (most notably Google) and more general information resources (most notably Wikipedia). A resource like VMoC needs a critical mass of support for its maintenance, with a community built around it to sustain its currency. Wikipedia has such a critical mass of both contributors and users. As a result, the founder of VMoC now contributes to this widely used resource instead of maintaining VMoC.

Regarding the London Science Museum, both Exhiblets and Ingenious underpinned the critical need for joined-up resources, cross-disciplinary and functional expertise, and, importantly, a shared vision. Storytelling in semi-linear ways was central to their success as web-hosted resources. At the time of Ingenious, website technology, content, and delivery had more challenges, to integrate each holistically, but these challenges also led to subsequent developments towards more standardization across systems, prototyping, and reusable templates and toolkits to support growing demands of a website presence and accessibility for an ever-increasing diversity of audiences and organizational goals. Two decades forward, efforts across the Science Museum Group have continued to focus on innovation regarding web design and the personalized experience – curated, self-guided and participatory, connecting people and stories inside and outside the Museum and beyond geographies. These combined shifts are strongly reinforcing the importance of digital technologies in engaging communities, both locally and globally. Consequently, there are growing perceptions about the necessity to further address broader social, economic, and cultural changes that are shaping communities, museums, and their place in society. The next-generation museum websites will be key entry points to these converging elements of dialogue and exploration.

The Virtual Leonardo and Leonardo's Ideal City projects highlighted both the educational potential of cooperative 3D worlds and the difficulties of creating stable, reliable and usable mass platforms when technology is not mature. Both systems should be viewed as proofs-of-concept rather than refined projects; the fact that even today metaverse systems are still rather difficult to use and usually lack the critical mass of users able to make them interesting, compared with 2D systems like social media (with the notable exception of online gaming systems like Roblox and Fortnite) should make us reflect about the importance of engaging human interaction and usability in online 3D systems, where fancy graphics are only a small factor for the system to be successful. Therefore reflecting and understanding "what went wrong" in past tech projects can provide essential insights to better orientate future investments by cultural institutions.

The purpose of this paper is to provide several first-hand descriptions of early museum-related website development, when the technology was still immature and evolving rapidly, with individual reflections of those involved. We hope that this will be of use to other independent researchers in more wide-ranging surveys of such developments, reaching some more general conclusions.

Ultimately, changing technology has a huge effect on the longevity of online resources. What was appropriate in the 1990s and 2000s is no longer necessarily supported today. It can look old-fashioned and "clunky" by modern standards. Since this early period of the web, there have been significant developments in mobile technology and apps (Filippini-Fantoni & Bowen 2008; Boiano et al., 2012) and online games (Boiano et al., 2022), for example. New technologies such as artificial intelligence (AI) and chatbots help to provide more interesting interactive experiences for users (Gaia et al., 2019). Digital culture for people in general (Bowen & Giannini, 2014; 2021) and especially concerning museums in the context of this paper (Giannini & Bowen, 2019) has been developing rapidly. Museum users and visitors expect increasingly participatory experiences (Boiano et al. 2019). Museums have also involved the public in citizen science to increase their participatory nature in a mutually beneficial way (Borda & Bowen, 2020), Developers of online museum resources can aim to reuse existing digitized and born-digital material in new innovative ways, as well as adding new material, embedded in the emerging metaverse, for example. The digital future for museums is likely to be as exciting, fast-moving, and interesting as it has been for the past three decades (Bowen & Giannini, 2019), accelerated as it has been by the COVID pandemic (Bowen et al., 2021; Giannini & Bowen, 2021; 2022).

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