Museum Education Between Digital Technologies and Unplugged Processes. Two Case Studies

Alessandra Carlini

Abstract This document presents the results of architectural design and prototyping of educational kits within the museum context, two case studies featuring a combination of digital technologies and unplugged processes. The field of application is cultural heritage and the topics are part of school curricula. The first case study is a museum display of digital video installations and educational kits that reproduce mechanisms of symmetry from patterned flooring ("www.formulas.it" laboratory, Department of Architecture, Roma Tre University and Liceo Scientifico Cavour" high school). The second case concerns the setting up of a school fab lab in which 3D-printed prototype educational kits are made for schools and museums in Rome, in partnership with the Municipality of Rome and the Ministry of Cultural Heritage and Activities (General Directorate for Education and Research). The cases involve professional, research and didactic experiences which led to funding-supported projects. The experiences showcase good practices in informal and cooperative learning, and highlight the relationship between education and popularization that draws on our architectural heritage.

Keywords Museum education · Architectural design · Educational kit · 3D printing · Digital manufacturing · Fab lab

1 Introduction

Digital technologies are transforming traditional learning methods. What are the implications of this for the museum's role in lifelong learning and in today's knowledge-based society? In some of the experiences we describe, unplugged activities and digital technologies are used to increase motivation and spark interest and curiosity in learning . Although targeting people of different ages and backgrounds,

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the projects are particularly effective in informal learning contexts in public schools. The field of application is cultural heritage. The teaching of STEAM (Science, Technology, Engineering, Art, Mathematics) subjects is at the heart of the creative process, calling attention to soft skills and a more conscious digital citizenship, as required by the National Plan for Digital Education (PNSD) [1]. All prototype kits were used in a hands-on, peer-to-peer workshop. Finally, the experiences feature best practice examples of "authentic tasks" [2]. In a context of "laboratory teaching" [3] and "competency-based learning" [4], they pose an open-ended question by simulating real contexts.

2 Museum Display for Science Popularization

This section presents the experience of designing for science popularization in a museum context. The goal is the study of symmetry trough the visual stimuli provided by historic artifacts (geometric pattern paving). In the first case, the communicative potential of digital tools is exploited when an exhibit is created that centers around the relationship between the museum space and the visitor. Digital tools provide an experiential stimulus for mathematical content. In the second case, the museum is an "authentic" setting for developing scientific teaching skills, and for designing educational kits on the subject of symmetry, for use in activities taking place at the museum.

2.1 Video Floor Installation Showing Symmetries in Motion

The first design opportunity took place at the Genoa Science Festival, 2007. The "www.formulas.it" laboratory (Department of Architecture, Roma Tre University) presented the exhibition entitled "Mathematics and Archeology" (scientific supervisor Laura Tedeschini Lalli, Roma Tre University). The original appearance of the floor is reconstructed with virtual animations starting from the archaeological fragments found on site (Trajan's Markets, Rome, imperial period), by applying the mathematical theory of periodic tessellation [5]. In the exhibit a video installation is projected onto the floor, rather than a screen, because the object is mathematical and related to architecture (Fig. 1).

The floors appear from above and visitors can walk on them. Perception and conceptual content are linked through physical experience.

This method seeks constant interaction between the Italian experience on science popularization linked to the school of Enrico Giusti ("Garden of Archimedes", first mathematics museum, currently in Florence, Italy), and 20th-century museography.

Fig. 1 The video projected onto the floor and, at the top, a "Velarium" help recreate the original spatial dimension of the Roman *tabernae* and convey the correct proportions to the floor. The projected animations were created by Elisa Conversano

Herbert Bayer's experiments (1900–1985) at the Bauhaus Institute in Dessau (1919–1933) used the relationship between the mechanics of the eye and the physical dimension of perception as design tools [6] (Fig. 2).

After the Second World War, Italian architects like Carlo Scarpa (1906–1978) and Franco Albini (1905–1977) created museum installations in which they reflected on the relationship between content and container, by making a connection between the object and the physical dimension of perception. Both the experiences cited viewed

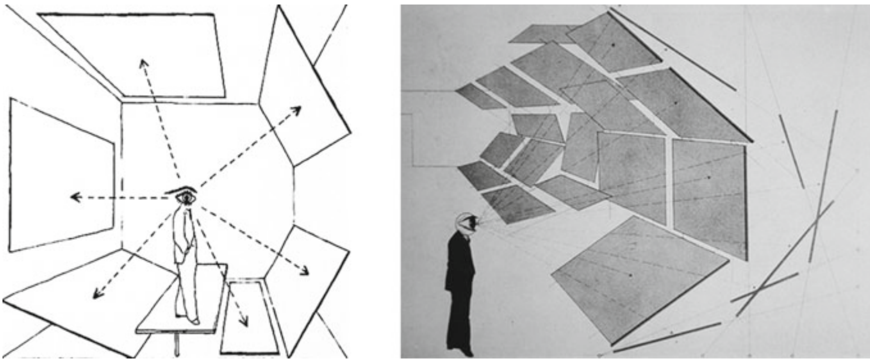

Fig. 2 Herbert Bayer, Werkbund Exhibition, Paris, 1930. The diagram shows the visual perception possibilities available to exhibition designers

museography as a system of relationships. The relationship between architecture and the popularization of science was discussed in Carlini and Tedeschini Lalli [7] and Carlini et al. [8].

2.2 Extended Museum of Cosmati Floors. Educational Kit

The experience described in the previous paragraph inspired the 2016 project "Educational kit for an extended museum [9] of Cosmati floors", a PCTO (training course in transversal skills and orientation) for the "Liceo Scientifico Cavour" high school and the National Museum of Palazzo Venezia (Rome, Italy; Director Sonia Martone). Carried out with architect Teresita d'Agostino, the project is mentioned as one of the Ministry of Education's best practices [10] and was selected by CNR (National Research Council of Italy) for the conference "Officina 2018" [11] (Fig. 3).

In this case, the study of symmetries concerns the geometric pattern of Cosmati floors in Rome and Tuscania. The symmetry educational kit was made using digital and unplugged techniques: mirror rooms [12], inventory of magnetized pieces, smart tourism with immersive Google Cardboard, interactive map for smartphone [13]. Since 2017, the Ministry of Education and Research (MIUR) has included the project in the "Visiting Teacher" workshop activities for peer-to-peer teacher training

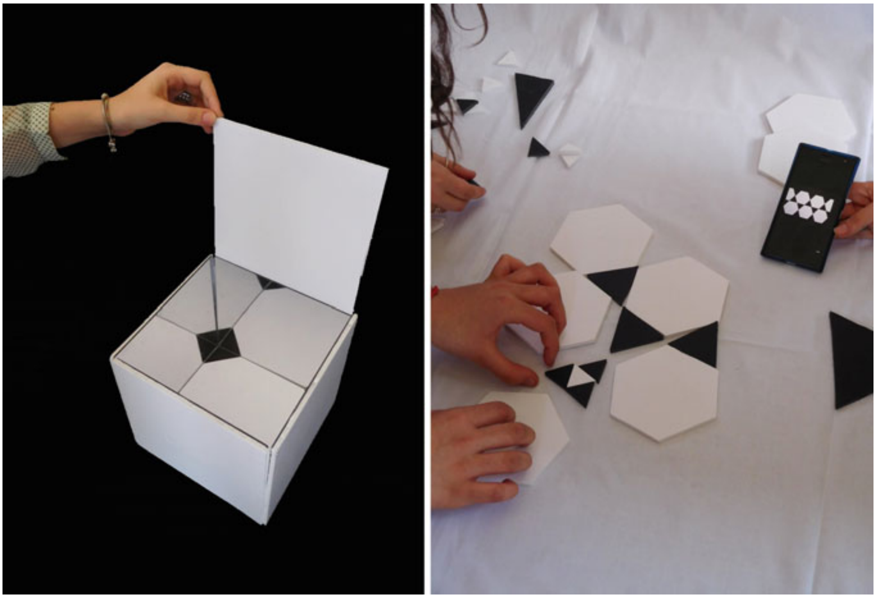

Fig. 3 Educational kit for the study of symmetries in Cosmati floors

in secondary schools (project managers at "Liceo Scientifico C. Cavour" school: Alessandra Carlini and Teresita d'Agostino).

3 Museum Education. Prototyping Educational Kits with 3D Printing in the School Fab Lab

The educational potential of a school fab lab is illustrated below. The structure was built at "Liceo Scientifico Cavour"school in Rome (headteachers: Ester Rizzi 2017; Antonella Corea 2019; Claudia Sabatano 2020) together with Antonina Amadei, the school's digital coordinator. The goal was the creation of a learning environment open to local institutions, a prototyping center for educational kits with a 3D printer, applying the living lab approach. This strategy uses digital fabrication to stimulate scientific inquiry and inclusion, by strengthening the role of science as an economic lever in the knowledge society. Museum education also means using the museum as a learning environment, not merely for the passive enjoyment of cultural heritage.

The activities of a school fab lab provide an experiential approach to knowledge that uses the body as a cognitive tool through the tactile exploration of objects made with a 3D printer, and direct engagement with historical and cultural heritage. The experiment fits into the cultural context of the "Tactile Laboratories" developed by Bruno Munari (1907–1998) after his "*Le mani guardano*" exhibition (Palazzo Reale, Milan, Italy, 1979) [14].

Students aged 16 to 18 in the third or fourth year of *Liceo Scientifico* engage with younger students, aged nine upwards, at hands-on workshops conducted with prototype models printed in the school fab lab. The goals are: inclusion through museum education; cultural heritage education through an experiential approach; informal education and cooperative learning; dissemination of science culture through visual and experiential input; development of digital manufacturing skills; new technologies applied to cultural heritage in the knowledge society. Skills were evaluated using: *Ex ante* evaluation (analysis of starting levels, *ex ante* observation section of MIUR protocol for PON-FSE 2014–2020 projects); formative evaluation (presentation of intermediate steps and review of partial results, intermediate observation section); and e*x post* evaluation (presentation of the results to a commission made up of teachers and external tutors, interviews, dissemination workshops, *ex post* observation section of MIUR protocol). The kit can be used in different contexts: educational workshops in museums; hands-on peer-to-peer workshops with younger students; curricular activities in the classroom.

3.1 Creative Geometry Kits: Detachable 3D-Printed Apollonius's Cone

The school fab lab was used to prototype a 3D-printed creative geometry kit for use in schools in the Municipality of Rome (2017) [15]. Students chose Apollonius's cone for project development [16]. This object allows the visualization of conic sections—circle, ellipse, parabola, hyperbola. The project uses magnetic surfaces to enable disassembly and reassembly. The cone, of which no other examples of "hourglass" or double-branch models are known, was prototyped using CAD software (Tinkercad, GeoGebra) and 3D printing (Cura) in the school fab lab (Fig. 4).

The project won the international prize at the 2018 edition of Maker Faire, Rome. Here, too, the didactic results were achieved through years of work, starting from the experience of the Ministry of Education's PLS (Scientific Degree Program) entitled "*Coniche e macchine da disegno*" (Conics and drawing machines) [17].

The activity takes place in four steps:

1st step—analysis of market attractiveness and identification of the topic through brainstorming;

2nd step—designing the prototype, including identifying parts, deciding on printing procedures and choosing materials and colors. Storyboard for the video tutorial on conic sections;

3rd step—development of the 3D model in Tinkercad and GeoGebra software; thematic insights, word and image processing for the video tutorial;

4th step—3D-printed (Cura software) prototype of the kit, surface finishing and gluing magnetized surfaces.

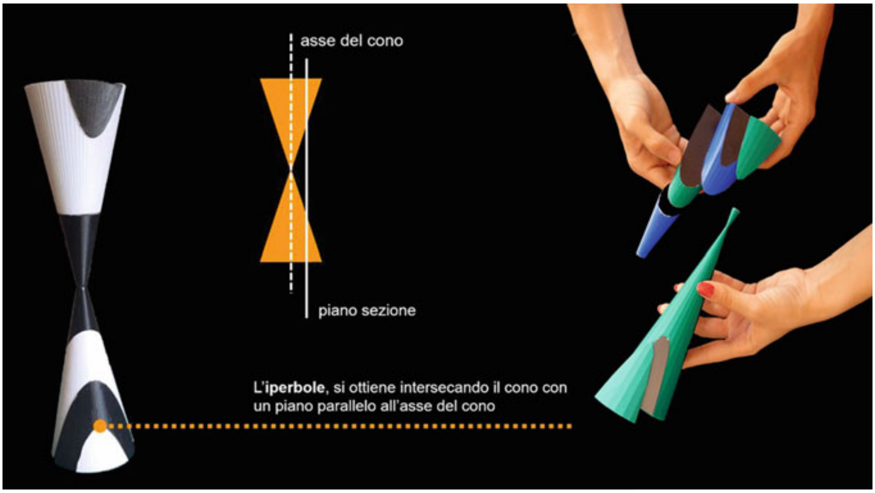

Fig. 4 Detachable apollonius's cone made with a 3D printer

Fig. 5 Tactile kit of Romanesque architecture in the National Roman Museum (Rome, Italy)

Inclusivity is one of the goals achieved with this project, with the teaching kit being used during curricular activities of recovery training gaps.

3.2 ART-TOUCH-LAB. Tactile Kits Made with a 3D Printer

The educational kit illustrated in Fig. 5 is a tactile device to improve museum access and inclusion. It was prototyped in the school fab lab and commissioned in 2019 by the Directorate-General for Education and Research of the Ministry of Cultural Heritage and Activities and Tourism (MiBACT). Autodesk software (Zephyr, Recap Photo, Meshmixer) and hardware (smartphone and 3D printer) were used to make a photogrammetric survey of Romanesque architecture and decorations [18].

The printed kit allows tactile exploration for the blind and the sighted. More generally, it is of interest to everyone as it stimulates cognition and is a different approach to art. The 1921 "Manifesto on tactilism" by Filippo Tommaso Marinetti (1876–1944) is a fundamental premise for any cognitive experience of art that uses sensory channels other than sight. The "Omero" tactile museum (Italy) is an important venue for social inclusion through art. The project was carried out with architect Teresita d'Agostino and won the PON-FSE "Alternanza scuola-lavoro" competition and was implemented with European structural funds (Partners: Centro S. Alessio per ciechi, Myosotis, Scuola Innovativa start-up; A-Sapiens. Evaluation: Daniela Liuzzi). In the context of STEAM, cultural heritage and museum inclusion is meant to encourage active citizenship: a more conscious digital citizenship, with inclusion as an instrument of democracy and popularization of scientific culture to reduce social inequalities. For these reasons, the program is one of the case studies in the training activities of the International School of Cultural Heritage (Fondazione Scuola Beni Attività Culturali, Italy).

The project takes place in four steps:

1st step—historical and artistic documentation;

2nd step—BYOD (Bring Your Own Device) photogrammetric survey of Romanesque architecture and art;

3rd step—data processing in a school multimedia laboratory using Autodesk software (Zephyr, Recap, Meshmixer);

4th step—3D printing of prototype tactile devices in the school fab lab.

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