# Design Thinking and Making at School

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## ABSTRACT

This paper offers a reflection on the role that HCI methods can play in educational school settings. We present exemplars of educational projects where designers, makers, educators and students developed educational kits to learn archaeology, history and geography collaborating in the design process from concept generation through to prototyping, building and experimenting at school. The projects used methods and techniques from participatory research-through-design as well as tools of digital fabrication (i.e. 3D printers and scanners, CNC cutting machines, electronic boards) to support teachers and students to fully exploit their potential. The objective of the design activity was to engage students in experiential peer-to-peer learning and to stimulate teachers in designing new educational activities working through creative prototyping processes.

The projects show that design thinking methodologies combined with the making practice can provide a fundamental contribution in supporting interdisciplinary learning, beside what is already happening for computational thinking and other technical disciplines.

### Author Keywords

Participatory research-through-design, Making, Design thinking, School, Interdisciplinary learning.

### ACM Classification Keywords

H.5.m.[**Information interfaces and presentation** (e.g., HCI)]: User Interfaces – theory and methods, prototyping, user-centered design, evaluation/methodology

## INTRODUCTION

HCI is profoundly routed in design thinking and making. While designer's sensibility, skills and methods are quintessential to match people's needs and desires, making and prototyping skills allow to experiment with solutions, and engage people in participatory design activities.



Since the late 2000s, HCI researchers have begun to discuss the potential of making and digital fabrication in the educational context [1]. The theme is rooted on three main theoretical pillars: Papert's constructivism [2], experiential education [3] and critical pedagogy [4]. In 2013, [5] organised a workshop at the CHI conference identifying areas of application of digital manufacturing in HCI including prototyping in the interaction design process, learning and constructionism, fabricated interfaces and artefacts.

In the last few years, the practice of making and digital fabrication has grown attracting the interest of professionals, educators, practitioners and the academic community for the informal, open, networked, peer-led and shared learning. In the school context, this practice can support the application of interdisciplinary educational approaches like STEAM, an approach to learning that uses Science, Technology, Engineering, the Arts and Mathematics to engage students in experiential learning, collaboration, and work through creative processes.

In 2015, the Italian Ministry of Education, University and Research promoted the Digital School National Plan (Piano Nazionale Scuola Digitale) [6] with the creation of “Creative Ateliers” in primary and secondary schools. These ateliers are educational maker spaces to stimulate making and tinkering and to combine physical and digital world in formal learning activities. In this vision, laboratory teaching takes a fundamental importance in promoting craftsmanship, creativity and interdisciplinary learning.

The Digital School National Plan provided funding for the schools to acquire 3D printers and scanners, robotics kits, electronic boards and other digital fabrication tools. However a discussion was raised among teachers on how these tools can be effectively and creatively used to reach educational objectives, and how educators can be trained to develop the necessary skills and competences to drive interdisciplinary learning in the creative atelier.

This paper presents exemplary projects where methods and approaches from HCI and participatory making were used to engage teachers and students of primary schools, makers and designers in developing educational kits for learning archaeology, history and geography. In these projects, participatory design activities held “Making” in their core. Participants were encouraged, through cycles of reflection-on-action, to develop ideas, prototype solutions, experiment with them and reflect on the achieved outcomes.

The projects were promoted by Santa Chiara Fab Lab (http://scfablab.unisi.it/), a strategic project of the University of Siena based in a large fabrication laboratory facility. The Fab Lab makes of multidisciplinary innovation one of its strengths. The facility hosts Italian and foreign students and faculty, researchers, craftsmen, (future) entrepreneurs, inventors, professionals, policy makers and simple curious. Santa Chiara Fab Lab offers a creative context for developing new ideas and promoting digital skills and knowledge, with a strong vocation to the development of a multidisciplinary culture.

## EDUCATIONAL GAMES

Three educational games were developed in a participatory research-through-design (RtD) process that engaged people with different competences, roles and skills in different settings: a university archaeology lab, Santa Chiara Fab Lab and a primary school [7]; [8]. Participatory RtD enables the development of artefacts that reflect and respond to emergent discoveries. The design process evolved in a series of workshops to exploit the local values and making practices, and to embed them in the design process. The design team included MA students in Experience Design from the University of Siena (Italy), a psychologist, archaeologists, designers with digital fabrication skills, school teachers, students of grade three, four and five.

The games were designed to support interdisciplinary learning of archaeology, history and geography, intertwining collaborative problem solving with narrative activities.

*Archeo* is a modular game composed a 18-piece puzzle depicting the story of a noble family living in Rome in 1527, and a collection of 18 wooden fragments of the replica of a bowl belonging to that family (Figure 1) [8]. The actual bowl was found during an archaeological dig and was presented during a workshop at the university Archaeology Lab. The bowl was scanned in 3D and the resulting model was then 3D modelled and scaled on the basis of the actual size of the real artefact.

With the intention of creating a game based on handling and assembly of physical elements and building objects, the modelled bowl was "cut" into 18 slices 3mm thick, which could then be assembled. The slices are made of wood, using laser cutting and engraving on a 3mm thick plywood panel. The same technology was then used to make the 18 pieces of the puzzle telling the story that provides the background for the game. The different pieces in the puzzle serve both to reconstruct the story from bowl to puzzle, or to reconstruct the correct order of assembly of the bowl starting from the puzzle.

**Figure 1. Archeo**

The second game, *Itinerarium* is inspired to the classic Game of Snakes and Ladders (Figure 2) [7]. It tells the story of Emperor Carinus and his wife Magnia Urbica as they travel from Germany to Rome, where Carinus is to be crowned Emperor. The game board is a reproduction of part of the Tabula Peutingeriana [9], a medieval copy of an ancient Roman road map (about 300 A.D.). The board was created using laser engraving and cutting techniques, and contains a representation of the map and 30 squares representing towns of the day with an imaginary road linking them in order. Players travel from one square to another by throwing two dices and following the instructions in the square they land on. The winner is the player who reaches the square representing the city of Rome first. Underneath the game board, corresponding to the squares, are cylindrical plastic containers, which may contain coins (reproductions of the ancient Roman coin explored during the workshops at the Archaeological Lab) or little sheets of paper. Players seek these items in the square, which provide instructions on how to proceed in the game or may offer trivia and stories about life in ancient Rome. 3 of the 30 squares are interactive, and when a token is placed on one of these squares, it permits reproduction of audio files telling stories linked both with the game and trip, contributing to the narration and development of the game.

An interactive lamp controlling time in the game was also developed from an accurate reproduction of the ancient Roman oil lamp presented during the initial workshops at the Archaeological Lab. During play, each player shakes the lamp after rolling the dices. An internal LED starts flashing with a "soft" fade-in and fade-out effect. The duration of the lighting of the lamp is randomly determined, and the player's turn is over when the lamp goes out entirely.

**Figure 2. Itinerarium**

The third game is *Playing geography* (Figure 3). It is a wooden geographical map of Italy realised as a puzzle. Each peace represents an Italian region. The kit comprises also a set of labels carrying the names of the regions created using laser engraving and cutting techniques, a number of 3D printed miniatures of Italian monuments, and other labels representing typical Italian products (e.g. oil and wine). Students have to compose the puzzle identifying the regions, their names, products and monuments. They also have to identify places of their own interest like “my grand parents’ house”, “ a place that I would like to visit” and so forth.

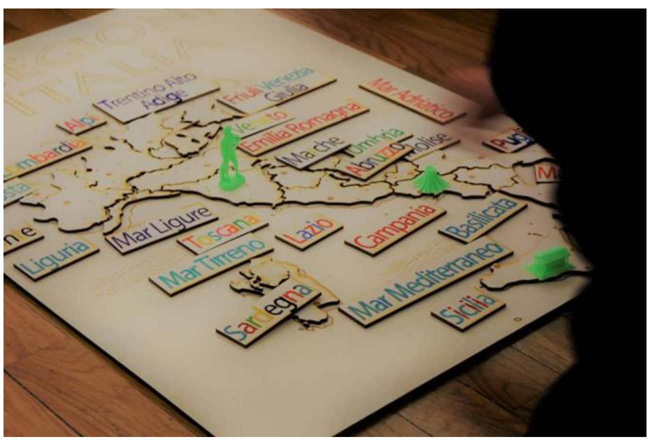


**Figure 3. Playing geography**

## LESSON LEARNED

The main lesson we learnt from the design cases described above is that design thinking and making are an ideal approach to scaffold participatory design of new educational activities, materials and contents. Material exploration, physical making and the construction of things provided the design team, including teachers and students, with an opportunity to think about and make around the learning practice, to build ideas that addresses technological matter as well as contents from other disciplines including humanities, to connect emerging technological opportunities with the lived experience at school.

As [10] found in their study, children showed to be most effectively able to participate as co-designers during middle stages when prototypes are available. Teachers were fundamental in an early design stage as well as during testing and reflections. Designers and makers were better positioned to prototype solutions with clear aesthetic qualities, that embody the theoretical underpinnings and scaffolds the generation and sharing of ideas. It is important to highlight the fundamental role that material objects (e.g. archaeological findings, 3D printed miniatures) play in the process. In our design cases, they provided a strong theoretical scaffolding to assist participants in formulating ideas and stimulating creative outputs.

## CONTRIBUTION

Within the practice of design in HCI, we see making as a powerful tool for confronting abstract assumptions with the reality of our concrete world. Making informs thinking, and vice versa.

Our design cases show that digital fabrication and making can play a fundamental role in bringing powerful ideas, literacies, and expressive tools [1] to students and teachers in the school context. The potential of making is no longer limit to computational thinking, programming and engineering. There is a growing call for educational approaches that foster creativity, inventiveness, narratives, and communication.

HCI and digital fabrication can provide unique tools and methods to support the development of new educational activities and interdisciplinary learning.

At the workshop how to support the spreading of HCI practices by discussing five principles outlined by [1] that exemplify advantages and perils of the introduction of digital fabrication in school:

- Educators should shy away from quick demonstration projects and take advantage of aesthetically pleasant products fabricated in fab labs. This promotes sensitivity to aesthetics and craftsmanship in students.

- Expose the students to failures and success deriving from iterative and incremental design processes typical of HCI.

- Promote interdisciplinary learning. As [1] states, mathematics and history as well as music and robotics become closely related in a fab lab.

- Contextualise learning in STEAM where knowledge from a discipline (e.g. programming) becomes a necessity for a history project.

- Re-evaluation rather than substitution of practices: students bring skills like construction, craft and carpentry from childhood to the school. These skills are progressively lost in mainstream curricula.

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