# Inscribing the conditions for a *Designerly Learning* in Elementary Classrooms : Building a Frame to Open a World of Possibilities

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**Abstract**
During six months of fieldwork in an elementary classroom (6-7 years old), we have looked for ways to transform an instructional classroom environment to allow a sustainable development of designerly learning. In this article, we retrace the evolution of this attempt with an instrumental perspective: through the description of some of the artifacts that we have designed, tested and discussed with a school-teacher, we derive a framework of the conditions to consider to develop this long term shift. First, we explain what is "designerly learning" and how it relates to digital literacy and fabrication. Then, we describe a series of artifacts, which compose a system of instruments that is referred to as a *frame*, and we discuss how such a frame can help scaffold and structure making activities in a classroom context.

**Author Keywords**
System of Instruments; Designerly Learning; Making;

**ACM Classification Keywords**
H.5.m.

## Introduction

There is a growing interest in digital fabrication from a learning perspective. Recent works, both theoretical and practical [5], have established the opportunities that digital fabrication offers for general education [3,4,8,24]. Several voices argue toward a broader understanding of digital fabrication for learning, and advocate for a holistic and designerly approach to digital fabrication and to "Making" [5,10,22].
Building on this learning perspective on digital fabrication, we explore ways to develop a profound and sustainable change in general education, to shift from instruction toward this designerly approach encompassed in 'making'. To do so, we have conducted a research through design that took place in an elementary classroom, with 26 pupils (6 to 7 years old) and a schoolteacher. During six months, we have worked together to transform an instructional pedagogy, and to implement a sustainable designerly learning. Our article retraces this research through an instrumental perspective, i.e.,by describing a system of tools co-designed with the teacher to support this shift, and their use.

Drawn upon previous literature, we detail the concept of "designerly learning", and we describe how it relates to digital literacy and digital fabrication. We then describe a series of artifacts we created in the classroom, and we explain how these compose a system of instruments. We discuss how our frame supports explorations, reflective thinking and collaboration; all these ingredients that enable the development of new potentialities for both the pupils and the teacher. From that instrumental perspective, we finally derive a framework of the conditions that enable the development of such *designerly learning*.

## Designerly Learning and Making

Learning sciences have acknowledged that embodied cognition and situated knowledge foster deep learning for decades, and new contributions in Child Computer Interaction (CCI) confirm this idea [16,18,21]. Students' access to digital fabrication tools is another great step towards more active and empowering pedagogies. Workshops and kits have been designed and evaluated, proving the beneficial impact of engaging students in making activities [4,5,10]. However, a question remains: why have these findings not changed general education? How can we create environments that propose such making activities in a sustainable way, not just for one-time workshops?

This issue goes beyond the question of digital fabrication. A plea for broader perspectives on digital fabrication has led to the propositions of a 'Maker mindset' [5], and of a 'Bildung' perspective [10], which refers mainly to self-development through creative processes. Echoing voices from various research communities [7,11,13,23], Smith et al., suggest that design thinking could be used in general education to provide students with a better understanding of creative processes [22]. They define design thinking as "the ability to thoughtfully engage in design processes of digital fabrication, knowing how to act and reflect when confronted with ill-defined and complex societal problems".

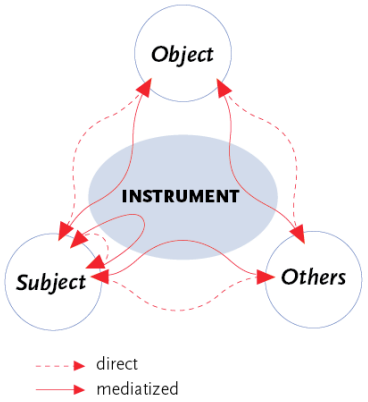



Diagram of the activities mediated by instruments (Rabardel) [17]

In addition to this, we believe a broader perspective is needed on digital fabrication, which we qualify as *designerly learning*. Referring to Cross' expression "designerly ways of knowing" [7], we consider ways of thinking and knowing as a core part of such learning, but we also emphasize environmental affordances and tools, be they digital or not. Extending the work of Petrich, et al. [17] from tinkering activities to classrooms activities, we believe that thoroughly designed environmental conditions to mediate their work, could help students to autonomously and responsibly achieve their goals, i.e., to choose the right means for an intended end. As Ackermann suggests, students have to experience the mediatisation of their experiments to understand the benefits of gaining new literacies [1]. "Children will have to embrace the reasons which led so many people before them to give shape to their ideas (by writing them on media that keep records of inscriptions), to use those shapes (as vehicles to get a better sense of their thinkings), and to ease their circulation (by adopting easily decipherable conventions)." Ackermann characterizes this reflective mediatisation as an "act of design".

Smith, et al. argue that design processes must be "highly structured, to enable reflective dialogs of the digital technologies, and people in everyday contexts." [22]. We stress that educational tools should be considered not only in terms of the pedagogical material they provide, but also in terms of the conditions they create within the classroom, and of their potential to support such reflective mediatisation.

## The instrumental approach

We refer to the activity theory and more particularly to the instrumental approach to shed light on the affordances and triggers that environmental conditions can represent. In the instrumental approach, the concept of instrument relies on two main components:

- A tool is an intermediary between a subject and the object of her/his activity[2,9,19].
- The constructive dimension of the subject's activity, and the design-in-use process [15,25].

Rabardel argues that an instrument is the combination of an artifact component (e.g., a tool) and a scheme of use [20]. This means that a tool becomes an instrument after a development phase called appropriation [9,12], where both the artifact and the schemes evolve [20]. In addition, an instrument does not exist in isolation: it composes, with the other instruments of the activity, in a 'system of instruments', that mediate the subject with the object of his/her activity.

This concept of instrument is of interest here for three reasons:

- It offers a theoretical framework to analyze how the classroom (the schoolteacher and the pupils) interacts with the tools that we introduced, and to understand the instrumental geneses (with the tensions and resistances that it creates) that seem fruitful for designerly learning.
- It places the instrument at the core of the analysis, which offers models to study multiple mediations from a subject's perspective during an activity.
- It acts like a 'mise en abîme', which resumes our educational perspective. It enables us to link the empowerment degree of one subject to his/her appropriation of his/her environment. Rabardel calls for subjects who act, transform the real and transform

themselves, and who use all their resources to better ground and adjust their activity [20].

## Case Study

*Methodology*

In order to get a sense of how *designerly learning* could practically be designed, we conducted an exploratory field study using a research through design methodology in an elementary school environment. In line with a growing researchers' advocacy [14], we worked in tight collaboration with a schoolteacher. We had two objectives: first, to develop a better understanding of the activity from a subject's perspective to study the impacts of transforming learning styles (regarding human development, critical and reflective thinking, social and economic rearrangements,…); and second, to gather strong insights about material and organizational conditions to foster transformations of teaching and learning activities that are sustainable, replicable and customizable. As Collins puts it, we aimed to contribute to "a systematic science of how to design educational environments so that new technologies can be introduced successfully" [6].

We were authorized to observe a classroom in a French public elementary school. We attended classes two to four days a week over a period of six months. In this classroom taught by an experienced schoolteacher (30 years of teaching), we observed 26 pupils, aged 6 to 7, who were learning the basics of reading, writing and counting. In collaboration with the teacher and iterating in short cycles, we took on a hybrid role that evolved from simple observations to full participation, designing educational tools and leading learning activities with the teacher and the pupils. After each session, we would spend two to three hours debriefing with the teacher and designing the next experiments for the next day.

During these six months, we designed several tools: most were co-designed with the teacher, but others were proposed by us without prior mutual discussion. Here, we present a series of these artifacts. Our aim in this article is not to evaluate their use by the pupils but rather to describe the learning principles that they address and how they tend to support the transformation from an instructional to a *designerly learning*. We are interested in:

- The discrepancies we experienced in the implementation process between the teacher's objectives and the students and teacher's activity, and
- The relations the artifacts have with one another.

*Description of the artifacts*

The artifacts that we describe can be classified into four groups, according to their main design principle (even though most of them have subsidiary aspects that relate to other categories): principles of organization, ways of assessing, understandings and tracks of processes, and management of the class resources (See Table 1 p.5).

ORGANIZATION

In order to enable pupil's autonomy in their learning activities, we have experienced the need to establish class rules and to structure activities over time, projects and people. Therefore, we designed four types of organizational tools:

- **A project board**. On this board, pupils place a paper with the name of their projects and add little

Table 1
Figures of some design proposals of the tools

Instrumental genesis

No instrumental genesis observed

Researcher's design

Co-designed with the teacher

Teacher's design

Co-designed by the researcher, the teacher and the pupils

Pupils' design

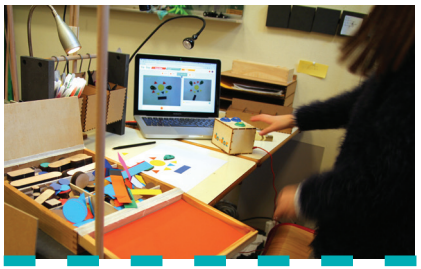
## ORGANIZATION

PROJECT BOARD | PUPILS BOARD (V2) | CLASS AGENDA | ACTIVITY SIGNS

## ASSESSEMENT

PROJECT BOARD | PUPILS BOARD (V1) | BALANCE

## PROCESSES



DIGITAL TRACES | WOOD BLOCKS | STORY-BOARDS

## RESOURCES

TOOLS AND MATERIALS | MOBILE SYSTEM FOR SMARTPHONE | WALLS DISPLAYS | DIGITAL LIBRARY

colored pieces of wood to declare the progress of their project (identification of steps, production, validation).

- **A class agenda** (daily planner). This wood board displays the projects from project board, and helps identify the projects that pupils will work on during the day. It also helps prioritize access to the production tools.

- **A pupil board** to identify daily roles and mentors. This instrument is used by the teacher, who daily allocates the meta-roles (journalist, delegate, provider), and by the pupils, who can refer to it. We tested two designs: nametags on paper and characters made out of paper with drawings.

- **Activity signs**. These were designed by the pupils after a collective reflective discussion about the different activities we had conducted. Each sign is a woodblock (drawn in a pixel style) composed of three pieces: the first indicates the topic of the activity; the second shows the amount of people involved (small group, individual, half the class or the whole class); and the third stands for the way of approaching the topic (manipulations, writing, research, production…) It is an open design for a signage that can evolve according to the new forms of learning that might appear.

### ASSESSMENT

The challenge here is to change pupils' expectations about who can assess their work, and foster self and peer assessment (instead of teacher/adults assessment). This is where the two organizational instruments played another major role:

- **The pupil board** can be used to identify pupils' successes, and remaining challenges. The first board with nametags was actually used by the teacher to place the pupils' names on a diagram: the closer they were to the center, the better they achieved their learning goals. This was a first step toward making pupils' skills visible to themselves and to the others, which enables acknowledgement of other's expertise. We could go further with the second design proposal and create stamps that could be added to pupil's ID to certificate their skills.

- **The project board** is used to organize collective critique moments where both the teacher and the pupils comment each project. The board allows to "note" and to track feedback with additional plastic pieces of different shapes that indicate whether a project has to be reworked or is satisfying.

- **A balance** allows to assess group work with plastic pieces. Pupils use it during small group activities by placing the pieces together on an axial scale, which reflects how they perceived their collaboration, and enables to discuss and report any problem.

### PROCESSES

One difficult but essential component of designerly learning is to shift the focus on the process rather than on the product itself. We encourage reflective thinking through diverse means:

- **Digital traces** can be captured during the activities via a cross-device platform. This is a way for pupils to keep track of their processes, which they can later organize into narratives and share as 'process histories'. The focus on traces allows pupils to reflect on their processes at different moments of an activity, which enables frequent step-back. A "journalist" can also be designated to collect traces for others during specific collective activities.

- **Personal and collective journals.** Digital tracks of processes can also be collected on personal diaries or even in a collective notebook.
- **Woodblocks and storyboards**. Keeping in mind a whole sequence is not an easy thing and often, the beginning of a plan gets lost before reaching the end. To capture this, we introduced two tools: woodblocks with Velcro and storyboard sheets of paper with pre-print squares.
- **Collective presentations.** As mentioned, each project leads to a narrative that is publically presented. This exercise invites pupils to find an appropriate way to communicate their process.

RESOURCES

We envision everything in the surrounding environment as a resource to be used and adjusted by the pupils for their learning purposes. However, instruments should be designed to organize and afford these resources as available and hackable:

- **Space and furniture**. Walls can be reinvested as large displays (we made tangible interactive displays with transparent rhodoid sheets that sticks on the wall and can be moved around). Tables should be movable and not attached to one pupil in particular to reconfigure the space according to the activities. A clear storage system makes the pupils go look for resources instead of waiting for the teacher to provide things**.**
- **People.** As mentioned earlier, others are a good resource and pupils have to acknowledge their classmates as such.
- **Good practices**. In order to show and share good practices with the whole class, we designed a mobile system to adjust and link a camera or a smartphone to a video-projector. This system is based on the old retro-projection system but instead of showing the teacher's 'slides', it shows the pupils' gestures or work in real time.
- **Tools**. Like in a making workshop, tools have to be displayed and accessible. We placed tools and different abstract objects that can become meaningful while being manipulated, to foster a 'bricolage' attitude.
- **Digital library**. In addition to a traditional library corner, we organized all the narratives produced by pupils on a platform that remains accessible at all times and create a class archive that can be consulted inside and outside the classroom.

## A Frame to opens up a world of possibilities

*Building a frame*

The system of instruments we set up regulated the time, the space and the subjects' activities in the classroom. It created a set of rules where each one had a defined role to play, with a clear understanding of what was expected from him/her.

Each of the four categories of the system took into account and formalized the three different mediations of the instrumental approach: from the subject with the object of the activity, with the others, and with herself/himself. Organizational instruments allowed pupils to acknowledge and situate their individual activities into a bigger picture of activities. Assessment instruments helped them evaluate their progress on multiple levels, and acknowledge themselves and other's expertise. Processes instruments supported keeping track of one's and other's paths, which generated individual and collective archives that the

pupils could later refer to. The resources, whether they were material or immaterial, because they were made reachable, hackable and were shared, enabled research-like and creative processes. Pupils generated a great variety of resources throughout the six months of our intervention. These had to be visible and stowed in systematic ways for later re-use.

This experience has led us to acknowledge how deeply connected these instruments are (and should be): a simple change in the design of one of them has an impact on the whole system, and correlatively on both pupils' schemes and learning mechanisms, and teacher's ways of teaching. Engaging pupils—and above all very young children—in creative processes is a hard challenge, and *making* activities have to be thoroughly structured so that the pupils do not get confused or anxious. *Designerly* does not imply no method or structure. That being said, as the classroom is seen as a community of practices, so the rules are continually renegotiated and adapted, as well as the instruments.

In future work, a collective design and research effort should focus on the instruments that compose such frame, taking into account the specificity of each context. Interrelations between instruments have to be studied in order to create the conditions of a truly effective learning through digital fabrication and making.

*Freedom and possibilities*

We consider this system of instruments as a strong frame for freedom. Within this frame, everything is allowed. For example, engaging pupils in ill-defined and wicked problems may not be an issue anymore: even though the process might be fuzzy and confusing, the multiple mediations proposed by the frame offer pupils rebound possibilities. *Making* activities, whether based on complex digital technology or not, do not have to deal with setting the whole time-space transformation of the classroom anymore. Thanks to such frame teachers could individualize their teaching methodologies, and switch from an instructional stance to a coach stance—and even learn with the pupils. Pupils could be more creative and adventurous because they are aware of the boundaries.

We see a great research agenda in such instrumental perspective. As for designers, constraints are necessary: they structure the whole process. Similarly, we consider the environmental and instrumental conditions of learning through *making* are at the heart of a sustainable designerly learning.

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