The Transformative Potential of Making in Teacher Education: A Case Study on Teacher Training Through Making and Prototyping

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Abstract. The paper describes an ongoing research on teacher education for the implementation of making and digital fabrication in educational settings taking part at LABoral Art Centre, Spain. It aims to define key points and indications for the design of learning environments for teachers through making and prototyping in the context of an art centre as an open education lab. We present a qualitative instrumental case study articulated around two dimensions: the analysis of the context of the art centre, and the design of two teaching education programs. The analysis of LABoral context aims to explore the potentiality of an open lab and its related community as a learning environment for teacher education. The study of the teaching education programs is set to define the principles in order to put forward a proposal for the design of a learning environment for teacher education in making.

Keywords: Making · Teacher training · Prototyping · Empowerment · Art · Design

1 Introduction

In the past 10 years, we assisted to the growth of several grassroots movements for the democratization of technology and invention, such as the diffusion of open-hardware rapid prototyping tools like Arduino, the development of the fab lab network and the 'explosion' of the maker culture. The diffusion of these tools and their use in communities are inspiring several sectors of the society for a switch from a user mentality to a creator one through the democratization of manufacturing.

If we look at maker culture as learning model we can say that it is an example of self-organized social learning that emphasizes informal, networked, peer-led and shared learning motivated by fun and self-fulfilment [1]. A growing number of practitioners and researchers belonging to the educational community see in maker-centred activities the potential for a pedagogical and methodological change in education based on empowerment of student through the creative use of technology and the access to tasks, such as programming and fabrication, previously reserved to experts [2–5].

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As Paulo Blikstein [3] argues the learning model of the emergent maker movement is based on three theoretical and pedagogical pillars: experiential education, constructionism and critical pedagogy. The ideas of Dewey [6], Fröbel [7], Montessori [8], Freire [9] and Papert [10, 14] are the 'bricks' of the theoretical framework of making as constructionist, experiential, emancipatory view of learning.

In the past five years, hundreds of papers and articles on making and the maker movement have been published. There is a general consensus in literature about the transforming potential of making-centred pedagogies and practices on learning. Mostly, the studies refer to the beneficial effects of implementing maker-centred education in STEM (science, technology, engineering, mathematics) subjects, but, also, several studies underline the potential of making experiences for personal empowerment, cognitive development and community building [4, 5, 11–13].

Maker-centred, constructionist learning environments have, of course, a tremendous potential for innovating educational practices, but, in order to make it real, we need to foster a constructionist culture in teacher education.

In a typical constructionist learning environment, children use technology to build projects that are significant for them. Constructionist teachers rarely follow a fixed curriculum, they act as facilitators of the individual learning process, not as instructors [3]. Also they understand learning as an active process in which the learner, constructs meaning through the interiorization of actions and sensory input in a social context where motivation is a key component.

We believe that in order to spread along the teacher community a maker-centred, constructionist approach we need to promote a methodological, political and epistemological change in teaching practice. We think we need to build a culture based on experimentation, design, invention, inquiry as key points in order to promote significant, situated learning with the students.

Due to the fact that implementation of making activities in education is quite recent, majority of studies focus on the effects it has on students learning. At the moment, there is still a lack of studies on teachers training in making. We decide to address our research to the design of a teacher training model.

We focus on making as an emergent inquiry-based educative practice that has the potential to make a change in traditional teaching practices of public school educators. We see making as an empowering opportunity for teachers in order to foster experimentation skills, encourage intellectual risk taking and improve agency and authorship. Making activities also foster the change of traditional social roles in class by establishing an equal relation between teacher and learner and treating expert/novice roles as fluid.

2 Design Based Research

We present a qualitative instrumental case study [15] articulated around the analysis of the context of the art centre on the one hand and on the other hand, a design-based research of the teaching education programs. The analysis of LABoral context aims to explore the potential of an open lab and the related community as learning environment for teacher education. The study of these teaching education programs (Dropout and AuLAB) is set to define the principles in order to put forward a proposal for the design of a learning environment for teacher education in making.

This approach to research enables us to study teacher training in making within the context of the art centre using a variety of data sources such as: participant observation; semi-structured interviews; focus groups; participatory learning environment design; participatory pedagogical evaluation; artefacts; context description.

3 Context: Art Centre as an Open Educational Lab

LABoral is an art centre that works in the intersection between art, science and technology. It operates as a structure of labs and areas that work interdisciplinary.

Bring artistic proposals to audiences is the main goal of every art centre. The creative process of most of the artists and curators is as important and interesting as their result, especially nowadays when proposals and statements get easily and quickly outdated. At the same time, research and production methodology is a didactic resource by itself, offering a very valuable approach to knowledge and social development.

Being surrounded by digital technology, a more active use of it or at least a better knowledge of its basis is proposed: workshops and education programs to empower audiences with tools and knowledge. In the case of fabLAB Asturias, digital fabrication laboratory at LABoral, we promote alternative approaches and techniques to traditional industrial creation processes.

With these goals in mind, the art centre operates as an open lab for technological, social and cultural exchange, allowing the interaction between different areas of activity and useful resources, creating a modular and flexible structure that combines research, development and production at the service of creators, educators, work groups, firms, entrepreneurs, school and university.

The idea of an art centre as a didactic resource has been there since the beginning of our education program in 2008, inviting artists to collaborate with teachers and schools, not to show education professionals how to teach, but to share their common expertise in order to find or create useful tools for the classroom. The opening of fabLAB Asturias in 2011, added the technological approach and a method for social and cultural exchange, together with TVLAB, an experimental television platform.

This scenario has given us the opportunity to develop a network culture around the art centre as a laboratory where teachers and students could participate but also policy makers and other institutions.

3.1 Experience: Dropout Prevention Program and AuLAB

In 2012, LABoral started a partnership with the Ministry Education of Asturias in Spain in order to develop a program of activities that aimed to build new learning spaces through research projects, supporting a change in the organizational and curriculum model, more specifically fostering knowledge of technical language in order to achieve a cross-cutting use of ICTs while also encouraging experimentation and critical thinking.

Dropout Prevention Program. Education program aimed to 39 students from 12 to 16 years old in danger of dropping out of the education system and their teachers. Dates: from September 10th 2012 to June 1st 2013. Goal: offer the community a program of activities adapted to the needs and interests of each group of students.

Aulab 2013–14. Education program aimed to 175 students and 20 teachers from primary to secondary school part of "Contrato Programa" (3 year innovation in education program for schools in Asturias). Dates: From July 2nd 2013 to June 1st 2014. Goal: collaborative design of a learning environment that allows exploration in the context of school curricula. This school year (2014–15), AuLAB continues working with 20 schools divided into three working lines: experimental television, creative programming and design and digital fabrication.

Both, Dropout prevention program and AuLAB are focused on the idea of empowering teachers, not only in their use of technology but also into developing an inquiry-based educative practice, more adequate for the students' needs, offering at the same time, a new perspective of their role as educators that research and create their own tools and resources.

4 Teachers Training as a Co-design Practice of Making-Centred Learning Environments

In both programs, teacher training is planned as a participatory research aimed to design and evaluate prototypes of educational activities which use digital fabrication as an instrumental resource to build experiential learning environments in a Fab Lab.

DBR -Design Based Research- was the methodology chosen because is a systematic but flexible methodology who helps to improve educational practices through iterative analysis, design, development, and implementation. It is also based on collaboration among researchers and practitioners in real-world settings, and leads to contextually sensitive design principles and theories [16].

DBR establishes a real investigation process in order to prototype education activities using digital fabrication as a tool. The practice of prototyping is extended from objects to activities allowing teachers to design learning environments where design, decision making, problem solving, cooperation, sharing, meaningful participation are strategies to work on basic competences where the design includes technological elements, as in our case, DBR allows capture interactions with the technology as well as interpersonal interaction. The data can be captured on several levels students, teachers, and researchers yielding multi-tiered design processes [17, 18].

The study detects a set of educational needs that we use as a base for the elaboration of the proposal for a teacher education model in making. Among other things, we detect the lack of tools and strategies related to emotional managing in the interaction with technology, the need of improving inquiry-based learning skills and the need to create a culture of documentation as a tool for experiential learning and making.

4.1 Emotional Management

Emotional managing is a key issue in supporting teachers during the process of methodological change in teaching practices. The swift to a more experiential teaching style requires the acquisition of emotional strategies related to these domains:

- Negatives attitudes toward technology;
- Managing frustration and failure;
- The interaction with students during the creation process.

The majority of teachers who participated in the programs referred to the fact of feeling really uncomfortable using technological devices in class. They feel they are not as in control of the process as their students and they feel unable to teach the class.

In experiential learning it is very important to manage frustration feelings and failure and consider them tools for enhancing learning processes. Tolerance to frustration and a positive attitude towards failure is a key issue in making. So teachers who want to implement making as an empowering learning tool need to be prepared to manage their own frustration in order to be able to support student in the creative process.

In the study, we observed that teachers show a lack of strategies for emotional managing of failure and frustration. They focus more on the construction of a physical product rather than on supporting the creative process. Teachers give instructions and tend to sequence, partitioning the process of the student in steps they think reasonable. Sometimes, they tend to control the process offering ready-made solutions. The emotional managing in this case should help teachers to understand and control the urge to intervene on the student's process, by avoiding judgments and control anxiety.

4.2 Inquiry-Based Learning

Inquiry-based learning is crucial in making, even more for maker educators. The disposition to get and share useful information through online communities or interest groups, is a very good and constructive attitude who can support teachers in building motivating learning environments based on experimentation and curiosity.

The more common attitude of the teachers participating in the programs, as part of a vertical, centralized structure as the public school system, is to receive instructions, in form of curriculum, and apply them rather than design original learning environments. Also, when they are trained in a new tool or technique they expect to receive a set of technical skills who allow them to use it in class with no need for autonomous inquiry and research.

In the case of making, the set of required knowledge and skills in order to fully use a makerspace or a Fab Lab is so extended that nobody has it all. For example, one should have good command of vector and CAD design programs, good command of 3D softwares for product design, also develop skills in soldering, electronic design, physical computing, mechanics, programming, fabrication skills, etc. In general, nobody has the complete set of skills required, so makers are used to learn what they need to know in order to realize a specific project they have in mind. It happens by connecting with experts and peers or using shared knowledge repositories.

During the teacher training we tried to inspire this way of working in the participants by asking them to define a project and try to get autonomously the knowledge needed to realize it. The majority of the teachers were reluctant, especially at the beginning. They feel lost and uncomfortable working without a fixed set of instructions to follow. A group of primary school teachers instead started to work spontaneously using peer support. Just a few individuals were able to start an autonomous inquire process.

4.3 Documentation

Documentation is a key element in the design of experiential learning environments. Actually it is the missing ingredient in traditional thinking about assessment and self-learning. Many teachers involved in "maker" programs and schools are familiar with the idea of documentation as base for assessment and formative (pedagogical) evaluation. Documentation helps to build shared knowledge and allows teachers to reflect on their teaching practices.

During the teacher training, we tried to persuade and motivate participants to construct a meaningful documentation of the project they were realizing, but their reluctance was very hard.

Analyzing the beliefs of teachers we detect the lack of a culture of documentation. Documentation is seen as something useless, a form of control by the institution. It appears participants do not to appreciate correlation between documentation and collective construction of knowledge.

4.4 Getting Started

Getting started with the design of making-centred learning environments can be overwhelming for a novice, specially a teacher who is not too familiar with technology. The design of the first maker centred experience is critical, because the complexity involved in making can lead the participants to quit.

We detected that is quite effective reduce that complexity by dividing the process in modular units. Modular activities allow the participant to build something meaningful with reasonable amount of technological complexity involved. By achieving the construction of a new module the participants feel more confident and motivated to combine several modules in order to build a more complex prototype.

5 Proposal for a Teacher Training Model in Making

The proposal is articulated in three phases.

Phase 1 Initiation. Introductory set of activities aimed to set in motion a process of empowerment in order to get passed negative attitudes around technology. Duration: 40 h. 3 days intensive workshop, 2 weeks workshop, 3 h/day.

Phase 2. Training in practice: teachers co-design learning environments and work together with students. The materials and conclusions will be evaluated in order to work on an approach that can be exchangeable. A research process is put in place, analyzing and evaluating results. Duration: 6 months (workshops) + 6 months (evaluation and testing groups).

Phase 3. The creation of a permanent network, an education laboratory in order to foster practical research and peer support. The exchange of documentation and results plus the participation in conferences where educators share their experiences offers the context, also fab labs can operate as the spaces for meeting, researching and trying out materials.

5.1 Phase 1: Initiation

The initiation aims to work on there different aspects:

- Fostering positive and confident attitude towards the creation of technology and its use;
- Offering a meaningful making-centred "I can do it" experience aimed to show the participant that he/she is able to act on and with the design of artifacts;
- Promoting acquisition of technical skills in order to design the first learning environment for the students.

The initiation consists in an intensive three-day training based on the ludic creation of technological artifacts in group. The time is a key point: working intensively allows teachers to get familiar with the environment and tools and accomplish, at least, one creation activity. The achievement of just one simple construction make the teacher more confident and able to go on learning and creating.

During all the process, it is extremely important to support the participants emotionally, pedagogically and technically. Facilitators help to manage the complexity of the environment by dividing it in simpler modules depending on the situation.

The training is designed on a constructionist base, the same that will be used for the activities in the classroom. Teachers should have the same experience as their students in order to foster the reflection on every aspect involved in maker-centred activities.

The initiation wants to offer a significant learning, it is not a simulation. For this reason, we ask the teachers to design and fabricate some artifact they really need for their practice in class or for research tasks.

The creation of a real artifact from scratch might be really hard, but with the adequate support it is not impossible. The struggle of participants during the process allows them to self analyze all the aspects involved in a making and understand how to design and facilitate making centred-activities.

Another important goal of the initiation is the acquisition of a set of technical skills. It is very important not to overwhelm participants with too much technical information. Teachers have to acquire just the basic set of technical skill they need in order to design their first simple maker-centred activity with the students who will take place at the next step: the training in practice.

5.2 Phase 2: Training in Practice

During this phase, teachers co-design together with researcher the learning environment they will implement with students. Then students, teachers and researcher will work together realizing projects during the entire school year.

The co-design of the learning environment is planned as a DBR -Design-Based Research- where the participants prepare, prototype, test and evaluate the proposed learning environment.

During this process, teachers are enabled to work on:

- Facilitation of creative processes;
- The development of a no-instructive teaching style;

- Iterative cycles of design and re-design of learning environment and prototypes;
- Acquisition of strategies for assessment and pedagogical evaluation through observation;
- Organization of work space as a pedagogical tool.

Configuring the workspace is a very important issue in the design of making-centred learning environments, as it is a very powerful tool for teaching. It is not necessary to have a full equipped fab lab in order to start a maker-centred project, but it is very important to understand how to design the space in order to foster creation and participation in students and other teachers.

The co-designed space will be the start point for the next phase of training: the permanent network as education laboratory.

5.3 Phase 3: The Education Laboratory

The education laboratory is a conceived as a community of practice [19]. Its main goals are:

- Design learning environments;
- Prototype educational materials;
- Design and implement of peer training, mentoring, learning groups;
- Foster interest about maker-centred education in the school community (teachers and families);
- Network with bigger community and interesting projects.

Training in making requires a constant effort. Tools and strategies are continuously evolving thanks to the contributions of the huge maker community and the technological development. For this reason the implementation of making in educational contexts has to be based on permanent training, participatory knowledge construction and connection with virtual and local community.

The education laboratory should be both a repository for tools and material and a community for practice. In other words, it should be a group of people sharing a concern for experiential education and their passion for making, who act and learn better as they interact regularly in a dedicated space.

Members of a community of practice engage in joint activities and discussions, help each other and share information. Members of a community of practice are practitioners. They develop a shared repertoire of resources: experiences, stories, tools, ways of addressing recurring problems—in short a shared practice. They build relationships that enable them to learn from each other [20].

6 Discussion

6.1 Teacher Training Model and Education Lab

In order to spread along the teacher community a maker-centred, constructionist approach we need to promote a methodological, political and epistemological change

in teaching practice, fostering a culture based on experimentation, design, invention, inquiry as key points for education.

This training will require to activate processes of emotional managing, especially those related to frustration and failure; promote an attitude of no-intervention in the interaction between teacher and student: pedagogical observation in stead of instructional intervention; advocate for reflection on practice and collaborative knowledge construction and integrate training in the context where learning is happening, an environment preferably rich in technology.

About the education lab, in order to foster the creation and preservation of the permanent education lab we plan to act with the same spirit recommended for the "cultivation" of communities of practices [19].

Opposite to traditional organization, this lab fosters participation better than directing and organizing. The empowering effects of this kind of structure depends on the voluntary engagement of their members, so we envision an environment in which the community of the education laboratory can prosper valuing the learning process, the time and resources available and encouraging participation and removing barriers.

6.2 Teacher Training Through Making Beyond the Education Community

Being a production centre, artists and developers work side by side with educators and students, sharing Fab Lab's resources and exchanging knowledge and ideas they later add to their own practice.

It is important to say that artistic community working at LABoral or participants in the professional and public programs go through the same self learning process based on finding and creating tools as they move forward in their research. The community around fabLAB Asturias includes not only makers and advanced users but also professionals interested in incorporating DIY practices in their everyday activities.

This experience and methodology spreads to community and media around LABoral, which being and art centre gets a lot of attention from media.

At this moment, LABoral is collaborating with Spanish collectors to put together a long term grant program aimed to develop education tools for schools based on some of the conclusions explained in this paper: promotion of self-learning in students and ongoing research for educators.

As for the next step in dissemination, a seminar is planned for 2016, inviting experts and education projects to share experiences; it will also include workshops in digital fabrication for educators.

Also in 2016, it is planned to start collaborating program lead by Vejle Municipality, Denmark. LABoral will participate with 4 schools and fabLAB team will focus in prototyping a teachers training short program.

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