Teacher Training through Making and Prototyping

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Abstract
The paper presents the preliminary results of an ongoing design-based research about learning environments for teacher education in making, taking part at LABoral Art Centre, Spain. It aims to define key points and indications for the design of learning environments for continuos training of active teachers through making and prototyping.

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Teacher training, prototyping, empowerment, design.

ACM Classification Keywords
K.3.1 [Computer Uses in Education]

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 shift 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-fulfillment [1].

A growing number of practitioners and researchers belonging to the educational community see in maker-centered 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, 3, 4, 5].

As 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, 11] are the ‘bricks’ of the theoretical framework of making as constructionist, experiential, emancipatory view of learning.

There is a general consensus in the literature about the transforming potential of making-centered pedagogies and practices on learning. Mostly, the studies refer to the beneficial effects of implementing maker-centered 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 [12, 13, 14, 4, 5].

Maker-Centered, constructionist learning environments have a great 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-centered, constructionist approach 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. We see making as an instance of the more general pedagogical approach of learning by design, considered by several researchers as a promise for teacher learning [15, 16, 17]. Also we see maker-centered pedagogies as an instance of student-centered, educational experiences such as Reggio Emilia approach and the Metodo Bruno Munari[1].

It is important to make clear that although technology is very central part of maker-centered learning environments, making as a mindset or learning model can be developed with no need for hi-tech equipment.

Design research

The research goal is to define design principle and a proposal for the design of a learning environment for teacher education in making.

The methodology chosen is design based research (DBR). DBR 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 [18].

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 [19, 20]. Also DBR enables us to study teacher training in making using a variety of data sources.

We first developed a preliminary design model based on literature review and consulting experts, then we applied it in 4 implementations. The preliminary model was based on two modules:

- teachers training as a participatory research
- a set of workshops and working sessions with students and teachers during the school year.

The training was planned as a group inquiry aimed to produce and evaluate prototypes of educational activities which use digital fabrication as an instrumental resource to build a proper learning environment in a Fab Lab. Duration: 4 sessions at the beginning of the school year.

The intensive workshops and the working sessions were aimed to bring to practice the activities produced during the teacher training with the students. Each group of students and teachers participated in intensive workshops during the first part of the school year. They also attended 8 working sessions of more product-oriented activities. The researcher was facilitating the teacher training and the intensive workshops. During the working sessions students and teachers were working with the fabLAB manager.

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[1] http://www.brunomunari.it/index2.htm

During every implementation we made modifications to the preliminary design model based on the analysis of the collected data.

The study is currently in the phase of retrospective analysis of the set of data collected during the 4 design cycles. The retrospective analysis will be structured as a multiple case study. The aim is to get a deeply understanding of the educational needs detected during the process.

Participants and implementations
Dropout Prevention Program. 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.

Aulab 2013-14 175 students and 20 teachers from primary to secondary public schools. Dates: From July 2nd 2013 to June 1st 2014.

Aulab 2014-15 141 students and 14 teachers from primary to secondary public schools. Dates: From July 2nd 2014 to June 1st 2015.

Aulab 2015-16 aimed to 42 students and 13 teachers from primary to secondary public schools. Dates: From July 2nd 2015 to June 1st 2016.

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.

Data

Participant observation; semi-structured interviews; focus groups; learning environment co-design; reflective practice, teacher journals, participatory pedagogical evaluation; artifacts; context description.

The observation took place during every session of teacher training and during the student/teacher workshops. It was made by the teachers and the researcher herself.

Outcomes

Through 4 cycles of iterative design we detects a set of educational needs. Among other things, we detect the lack of 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.

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 reflect on 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.

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.

Documentation
Documentation is a key element in the design of experiential learning environments [22]. 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.

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

We detected that it 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.

Proposal

Based on the analysis of the collected data during the 4 implementations we start to envision a proposal for the design of a teacher training in making. The proposal is articulated in three phases.

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-centered “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 learner’s needs.

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-centered activities.

The initiation wants to offer a significant learning, it is not a simulation. 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-centered activities.

Another important goal of the initiation is the acquisition of a set of technical skills. Teachers have to acquire just the basic set of technical skill they need in order to design their first simple maker-centered activity with the students who will take place at the next step: the training in practice.

Phase 2. Training in Practice
During this phase, teachers co-design together with researchers the learning environment they will implement with students. Then students, teachers and researchers will work together realizing projects during the entire school year.

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-centered 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-centered 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.

Phase 3. The Education Laboratory
The education laboratory is a conceived as a community of practice [23]. Its main goals are:

- design learning environments
- prototype educational materials
- design and implement of peer training, mentoring, learning groups
- foster interest about maker-centered 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 [24].

DISCUSSION

In order to spread along the teacher community a maker-centered, 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 [22].

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.

References

1. SHARPLES, M. Innovating pedagogy 2012, the Open University www. open. ac. uk/blogs/ innovating. 2013.
2. EISENBERG, Michael. Pervasive fabrication: Making construction ubiquitous in education. In: Pervasive Computing and Communications Workshops, 2007. PerCom Workshops' 07. Fifth Annual IEEE International Conference on. IEEE, 2007. p. 193-198.
3. BLIKSTEIN, Paulo. Digital fabrication and 'making'in education: The democratization of invention. FabLabs: Of machines, makers and inventors, 2013, 1-21.
4. MARTINEZ, Sylvia Libow; STAGER, Gary. Invent to learn: Making, tinkering, and engineering in the classroom. 2013.
5. QUINN, H.; BELL, P. How designing, making, and playing relate to the learning goals of K-12 science education. Design, make, play: Growing the next generation of STEM innovators, 2013, 17-33.

Dewey, J. The Child and Curriculum. University of Chicago Press, Chicago, IL. 1902.

Fröbel, F., & Hailmann, W. N. The education of man. D. Appleton, New York. 1901.

MONTESSORI, Maria. Spontaneous activity in education. R. Bentley, 1917.

FREIRE, Paulo. Pedagogy of the oppressed (MB Ramos, Trans.). New York: Continuum, 1970, 2007.

PAPERT, Seymour. Mindstorms: Children, computers, and powerful ideas. Basic Books, Inc., 1980.

PAPERT, Seymour; HAREL, Idit. Situating constructionism. Constructionism, 1991, 36: 1-11.

DOUGHERTY, Dale. The maker movement. innovations, 2012, 7.3: 11-14.

DOUGHERTY, Dale. The maker mindset. Design, make, play: Growing the next generation of STEM innovators, 2013, 7-11

HONEY, Margaret; KANTER, David E. (ed.). Design, make, play: Growing the next generation of STEM innovators. Routledge, 2013.

BANNAN-RITLAND, B.; BAEK, J. Teacher design research: An emerging paradigm for teachers' professional development. Kelly, AE; Lesh, RA; Baek, JY Handbook of Design Research Methods in Education: Innovations in Science, Technology, Enginnering and Mathematics Learning and Teaching. New York: Routledge, 2008.

16. KALI, Yael; MCKENNEY, Susan; SAGY, Ornit. Teachers as designers of technology enhanced learning. Instructional science, 2015, 43.2: 173-179.

17. KALI, Yael; RONEN-FUHRMANN, Tamar. Teaching to design educational technologies. International Journal of Learning Technology, 2011, 6.1: 4-23.

18. COBB, Paul; GRAVEMEIJER, Koeno. Experimenting to support and understand learning processes. Handbook of design research methods in education: Innovations in science, technology, engineering, and mathematics learning and teaching, 2008, 68-95.

19. REIMANN, Peter. Design-based research. In: Methodological choice and design. Springer Netherlands, 2011. p. 37-50.

20. WANG, Feng; HANNAFIN, Michael J. Design- based research and technology-enhanced learning environments. Educational technology research and development, 2005, 53.4: 5-23.

21. KELLY, Anthony Eamonn; LESH, Richard A.; BAEK, John Y. Handbook of design research methods in education. New York: Routledge. (560 s). ISBN, 2008, 805860584: 111-130.

22. SCHÖN, Donald A. Educating the reflective practitioner: Toward a new design for teaching and learning in the professions. San Francisco: Jossey-Bass, 1987.

23. WENGER, Etienne; MCDERMOTT, Richard Arnold; SNYDER, William. Cultivating communities of practice: A guide to managing knowledge. Harvard Business Press, 2002.

24. WENGER, Etienne. Communities of practice: A brief introduction. 2011.