Teacher training in making through the co-design of learning environments

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Resumen

El articulo presenta los resultados preliminares de una design-based research (DBR) de un entorno de aprendizaje para la formación docente en making educativo. La investigación tiene dos objetivos principales. El primero es definir un conjunto de principios para el diseño de entornos de aprendizaje para la formación continua del profesorado en making educativo. El segundo es explorar y comprender las necesidades formativas de los participantes. Después de definir un marco teórico basado en los conceptos de Learning Design, making educativo y Teacher Design Research se presenta el desarrollo del entorno de formación a través del proceso de toma de decisiones. Finalmente se presenta un conjunto de necesidades educativas detectadas durante las cuatro implementaciones.

Palabras clave: Formación docente, Teacher Design Research, diseño de aprendizajes, making educativo.

Abstract

The paper presents the preliminary results of a design-based research (DBR) about learning environments for teacher training in maker-centred education. The research has two main goals. The first one is to define principles for the design of learning environments for in-service teachers in maker-centred education. The second goal is to explore and understand the educational needs detected among the stakeholders during the training. After defining a theoretical framework based on the concepts of Learning Design, maker-centred education and Teacher Design Research, we present the development of a generalised teaching model by reconstructing the process of decision making. Finally we present a set of educational needs detected during the four implementations.

Keywords: Teacher training, Teacher Design Research, Learning Design, maker-centred education

Introducción

In recent years several grassroots movements for the democratisation of technology emerged. The diffusion of open-hardware rapid prototyping tools like Arduino, the development of the FabLab network and the dissemination of the maker culture are instances of this phenomenon. The diffusion of these tools together with the dissemination of a maker-centered mindset are fostering a shift from a user mentality to a creator one in several sectors of society such as economy, manufacturing, community development and education.

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If we look at maker culture as learning model we can say that it is an example of self-organised social learning that emphasises informal, networked, peer-led and shared learning motivated by interest, fun and self- fulfilment (Sharples, 2013).

Making is an interest-based practice, where the apprentice takes responsibility for his own learning, getting rid of failures, debugging and dead ends. In the maker mindset failure loses its negative value and becomes a way to activate new paths and strategies for learning. Also, the maker culture disseminates a positive attitude around learning because the acquisition of knowledge is aimed to the creation of something meaningful and shareable. In this line, the maker movement can be seen as a knowledge building community (Scardamalia & Bereiter, 2006).

For all these reasons, a growing number of teachers and educational researchers see in maker-centered education the potential for a pedagogical and methodological change based on empowering students through the creative use of technology and the access to tools, such as rapid prototyping boards and digital fabrication machinery, previously reserved to experts (Eisemberg, 2007; Blikstein, 2013; Martinez & Stager, 2013; Honey & Kanter, 2013). However, if its implementation is not supported by a change in teaching practice toward a constructivist approach, the transforming potential will be lost.

For this reason we decided to focus the study on the definition of design principles for learning environments addressed to teacher education in making.

Theoretical framework

The theoretical framework of the study is builded around three pillars. The first one is the idea that maker-centered education should be considered an opportunity to generate education practices based on inquiry and cooperation. Maker-centered education in this line is an instance of all those active and critical pedagogies which, despite having existed for centuries, have never been implemented on a significant scale within the formal education system.

 In this perspective, maker-centered education is not limited to training professionals but is about inspiring people and strengthening their commitment to learning. It's about collaborative use of interdisciplinary inquiry tools and the creation of shared knowledge, driving a change in educational relationships towards a more fluid exchange between experts and learners.

The second pillar is the idea of the teacher as a learning environment designer. The concept in the result of the redefinition of the role of educators in a context where an immense networks of knowledge are available thanks to ICTs dissemination and the almost ubiquitous connectivity.

The third pillar is the TDR (Teacher Design Research) paradigm, a teacher training framework based on the practice of learning co-design as strategy for teacher education and research.En primer lugar, se llevó a cabo una búsqueda de artículos de revistas científicas en las bases de datos Scopus, Web of Science, Dialnet, Teseo y Google Académico, con las palabras clave siguientes: programación, educación primaria, Scratch y pensamiento computacional.

The maker-centred education as an instance of active pedagogy.

As Blikstein (2013) underlines, 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 (1902), Fröbel (1885), Montessori (1917), Freire (1970) and Papert (1980) are the 'bricks' of the theoretical framework of maker-centred pedagogy as a constructionist, experiential and emancipatory view of learning.

There is a general consensus about the transforming potential of constructionist making-centered learning environments. Mostly, researchers refer to the beneficial effects of implementing maker-

centered education in STEM subjects but, also, several studies emphasise the potential of maker-centered pedagogies for personal growth, cognitive evolution and community development (Dougherty, 2012; Martinez & Stager, 2013; Honey & Kanter, 2013).

Maker-centered constructionist learning environments have the capability of making educational practices more inclusive and learner-centered but, in order to make it real, we need to disseminate a constructionist approach in teacher practice.

In a constructionist maker-centered learning environment, students use technology in order to build meaningful, shareable artefacts that are significant for them. Constructionist teachers see 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. So constructionist teachers rarely follow a fixed curriculum giving instructions, but they act as facilitators of the apprentice's learning process (Blikstein, 2013).

This approach requires that the purpose of maker-centered education shouldn't be limited to training professionals but should be inspiring people and strengthening their commitment to learning. Maker-centered education should be about collaborative use of interdisciplinary inquiry tools and the creation of shared knowledge, encouraging people to become creators and driving a change in educational relationships towards a more fluid exchange between experts and learners.

Furthermore, as Blikstein and Worsley (2016) highlighted, the education community has to take on the role of guide of the implementation of makerspaces and fablabs in educational settings. Without an approach that places learning and freedom at its heart alongside critical, creative, multi/interdisciplinary and reflective knowledge of the technical competencies demanded by the market, maker-centered education will fail to generate profound change and will be just another example of a technological education hype ended up in a school closet.

In order to produce a real change through the implementation of maker-centered education is crucial to re-define the role of the teachers and think strategies for their education.

The teacher as a learning environments designer.

We live at a time when information is more available than ever. ICTs, the almost ubiquitous connectivity and the powerful actions of movements of democratisation of technological knowledge, connect us with an immense network of knowledge, mostly open and freely accessible.

Information and knowledge are no longer transferred exclusively through traditional channels like teaching. As indicated by Goodyear and Dimitriadis (2013), this is why we need to redefine the role of our educators and how we create and organise knowledge.

Their view aligns with King (1993), who sought to change how we view teachers (rather than a 'Sage on the Stage', they are a 'Guide on the Side'), and tries to overcome this view by casting the teacher as a designer of learning environments. By adopting a designer mindset, teachers have access to useful tools for identifying their students' educational needs and for supporting their students learning.

The teacher is still giving access to information and knowledge, but is also capable of designing environments where the student can explore, investigate, analyse, synthesise and build shared knowledge from the huge variety of cognitive and technological resources.

Design Learning is based on the idea that education is not just about transmitting information to a passive receptacle but it's about improving student's motivation and triggering cognitive abilities enabling students to learn autonomously (Laurillard, 2013). Education is conceived as an act of design, such as a problem-solving activity that leads to the creation of something that didn't exist before (Ertmer, Parisio & Wardak, 2013).

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Mor and Craft (2012) define Design Learning as the creative and intentional act of conceiving new practices, planning activities, and seeking resources and tools for reaching new educational goals within a specific context. The teacher in their vision acts depending on his knowledge of the field, on a pedagogical approach, on technology and practical experience. Doing so he generates new practices within these fields and supports the students as they work towards their learning goals.

The concept of design under this vision is based on Cross (2001), Latour (2008) and Schön (1987). That is, the idea of design as a discipline that is at once science and art. Schön, in particular, sees the educator, and other professionals, as designers who create devices and methods for solving problems. However he places more emphasis on the definition of the problem than on its solution.

Design in this vision is simultaneously a creative practice and a research process. It can be applied to complex contexts where analytical techniques fail. For Shön, design is not limited to the use of scientific knowledge for problem solving. Its value is extended to the creative potential of professionals, and to the value of their tacit knowledge. Based on this logic, teaching professionals are like practical researchers in a constant dialogue with the scientific community. On one hand, they base their actions on scientific theory and, on the other, they nourish the scientific community with the knowledge they generate.

The analyses by Latour (2008) and Mor, Craft and Hernandez-Leo (2013) offers a list of design learning characteristics which helps us to better understand:

> A process through which practitioners meet educational goals in a specific context.

> An art form: a technical ability and a creative practice.

> A science: a theory-based critical and reflective inquiry.

> A practice guided by ethics that identifies needs and proposes.

> A practice geared towards change.

> A practice of repeating processes to adapt and improve them.

> A practice that alternates between defining the problem and solving it.

> A humble practice that considers contextual limitations.

As stated by Dalziel et. al. (2016) and Koper (2006), design learning is about developing a descriptive framework for gathering and representing teaching and learning practices and exploring how this framework could support educators to adopt new strategies. It's about representing the teaching and learning processes that take place in the classroom and from there identifying all supportive actions taken by learners and teachers alike.

Another feature of Design Learning is the emphasis on sharing practices among teaching professionals. Design Learning is therefore a methodology that supports teachers to make decisions on the design of activities and interventions, and is an opportunity for peers to generate knowledge and training exercises together.

Teacher training through learning co-design: the TDR paradigm.

Researchers agree on the need for institutions to step away from the course-based training model, focused on specific technical skills, towards a model that can provide more learning opportunities (Stein, Smith & Silver, 1999).

The technical reasoning behind a teacher training model focused on developing technical skills and acquiring technological knowledge only goes so far in addressing the challenges faced by professionals who sometimes use indeterminate practices within complex settings.

When we talk about a teacher, we're referring to someone immersed in the complex world of the classroom to the extent that they understand it both critically and vitally. They are affectively and cognitively involved in its unclear exchanges, in analysing messages and interaction networks, in questioning their own beliefs and approaches, in proposing and experimenting with alternatives and in the ongoing reconstruction of the school world (Schön, 1987).

Professional training based on technical reasoning belongs to a hierarchy that views professional development as the process for resolving instrumental problems via the application of specialist scientific knowledge. According to Schön, ranking professional knowledge in this way causes a separation between research and professional practice, among other consequences. Researchers provide the knowledge for diagnosing and solving problems, and professionals feed their problematic or successful experiences back into the system as evidence for the research.

The alternative to the model we've just described is teacher training based on reflection in action and developing critical reasoning. It opens up a line of research, and is a more effective alternative for solving problems in the classroom (Schön, 1987; Carr & Kemmis, 1988).

Teacher training is viewed as an 'innovation area'; a space for experimentation and education where experiential learning, research and organisational creation of knowledge lead to improvements (Rodríguez, 2009).

In this line, in order to design the teacher model for maker-centered education, we choose to follow the TDR (Teacher Design Research) paradigm for teachers' professional training. As explained by Bannan-Ritland (2008) TDR is an emergent paradigm who aims to promote the professional growth of teachers as adaptive experts. It is based on the idea that involving teachers in deep, long cycles of learning design has the potential to promote a deep learning of content, foster their adaptive expertise and enable the rethinking of beliefs and teaching practice.

TDR invites the teacher to activate research processes in the classroom through the design of learning environments, didactical materials, curriculum or to participate in novel activities involving other teachers or researchers. The success or the failure of the design these activities prompts the teacher to reconsider her belief system and her teaching practice in a meaningful way.

Design processes provide the teacher with opportunities to reflect on the curriculum and environments based on the knowledge, beliefs and learning objectives that they set for students (Parke & Coble, 1997). Interaction with other teachers, experts and researchers can deepen their reflections (Borko, 2004), radically improve their learning (Ball & Cohen, 1996); Parke & Coble 1997), and improve the quality and validity of the devices developed (Penuel, Fishman, Yamaguchi & Gallagher, 2007).

Also, because of the collaborative nature of the TDR, learning co-design has the potential of filling the gap between practitioners and researchers generating a sinergy who helps, from one hand, to define and solve problems in the class and, from the other, allows the production of theory needed to spread successful practices and share innovations.

We applied the TDR design framework under the conditions explained by Bannan Ritland (2008) and listed below.

TDR should be applied when traditional teacher's professional development appears unequal to the task.

Training on making is a constant and ongoing process. Technologies and action plans evolve continuously based on contributions from the community and scientific advances. For that reason, the implementation of creative technology practices requires tools for generating continuous training processes based on self-training, collective knowledge building and access to technology and educational resources in person or remotely. Traditional course-based professional development, focused on the acquisition of technical skills are not enough powerful to enable the teachers design

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meaningful maker-centered activities and environments. On the contrary, TDR, seems to respond well to these constraints.

Teachers' professional development can be fostered through their direct involvement in multiple teacher design cycles.

The participants are involved in the design process from the very beginning. They participate in the decision making about every aspect related to the learning design, concept, development, implementation, evaluation and re-design.

TDR is viewed through a frame of diffusion of innovation

The resulting knowledge is situated and distributed. That is, knowledge is created in the context within which it is used, and is distributed among individuals, groups, spaces and symbolic contexts.

TDR requires a long-term intensive commitment to teachers' learning

For each one of the four implementations we worked with a group of teachers for a nine months time.

Methodology

Research goal

The research goal is to define a teaching model for teacher education in making.

Design Based Research

The methodology chosen is design based research (DBR), a systematic but flexible methodology who aims to improve educational practices through iterative analysis, design, development, and implementation. DBR is based on collaboration among researchers and practitioners in real-world settings, and leads to contextually sensitive design principles and theories (Cobb & Gravemeijer, 2008).

The data can be captured on several levels students, teachers, and researchers yielding multi-tiered design processes (Reimann 2011; Wang & Hannafinn, 2005]. Also DBR enables us to study teacher training in making, using a variety of data sources.

DBR is iterative; every iteration involves a preliminary model, its implementation, data gathering, evaluation and re-design.

We first developed a preliminary teaching model based on literature review and consulting experts, then we applied it in 4 implementations. During every implementation we made modifications to the preliminary model based on the analysis of the collected data.

In DBR, two kinds of data analysis are conducted during two different steps of the study. The first one is aimed to make design decisions during the implementation in order to adapt the model depending on the response of the participants. The second one is a retrospective analysis of the hole set of data gathered all along the design process. The retrospective analysis aims to get a deeper understanding of the educational needs detected during the process.

Research participants

During the 4 implementations, 395 students and 55 teachers from primary and secondary public schools from the Principado de Asturias, Spain, participated in the research; a researcher, PHD candidate from UAB, Applied Pedagogy Department, a lab manager from FabLab Asturias at LABral Art Centre. Table 1 shows in detail

Data sources

Several data source were used: participant observation; artefacts; semi-structured interviews; project reports; teacher journals, expert contributions as shown in detail in Table 2.

Data analysis

For each iteration of the teaching model we reviewed and analysed all the data sources listed in Table 2 in order to improve the design feature supporting teachers' learning and change those who were not. The analysis followed the following steps:

- identifying notable critical events related to the teachers' learning;

- triangulation of sources: look for critical events in other data sources;

- seek for commonalities between critical events;

- make design decision, maintaining beneficial features and eliminating detrimental ones;

- evaluation of the design modifications by repeating steps 1,2,3,4 in the next cycle.

Outcomes

In this section we describe the evolution of the teaching model through the analysis of the detected critical features and the related design decisions made for each implementation. We also analyse a set of common educational needs detected during the entire design process.

Design decisions

In Table 3 offer a summary of the detected critical cores and the related design decisions made for each implementation.

Educational needs

In this section we try to analyse the critical features encountered in the design process by grouping them in sets of general educational needs.

Emotional Management

Emotional management is a key issue in supporting teachers during the process of changing their teaching style. Especially the swift toward a constructionist experiential teaching style seems to need strategies related to these domains: negative attitudes toward technology; managing frustration and failure; the interaction with students during the creation process.

The majority of teachers referred to feel really uncomfortable using technological devices in class because they feel they are not as in control of the process as their students are.

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 maker-centered education. So teachers who want to implement making as an

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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.

We observed that teachers show a lack of strategies for emotional managing of failure and frustration. They are used to focus more on the physical product rather than on the creative process. They tend to give instructions or, sometimes, to offer ready-made solutions. The emotional management in this case should help teachers to be aware of the urge to intervene on the student's process, and try to avoid it by controlling anxiety.

Inquiry-based Learning

Inquiry-based learning is crucial in maker-centered education. The disposition and the practice of getting and sharing information seems to be a constructive attitude who can support teachers in design learning environments based on experimentation and curiosity.

The more common attitude we detected in participants is to expect instructions, in form of curriculum, and apply them rather than design original learning environments. Furthermore, when they are trained, they tend to expect a set of technical skills who enable them to use it in class with no need for further autonomous inquiry and reflection.

In the case of maker-centered education, the technical knowledge to fully use a makerspace or a Fab Lab is so big that nobody masters it all. A common strategy is to invite the participants to learn just what they need for the specific project they want to carry out, and seek for more information when is needed.

We tried to make the participants be inspired by this way of working by inviting them to define an idea and try to get the knowledge and the skills needed to bring it to life. Teachers were reluctant, they refer to feel uncomfortable working without fixed instructions for an open-ended task.

Documentation

Documentation is a key element in experiential learning environments. Actually it is the missing ingredient in traditional thinking about assessment and self-learning. Many teachers committed to active pedagogy are familiar with the idea of documentation as base for assessment and formative (pedagogical) evaluation. Documentation is the strategy to build shared knowledge and enable teachers' reflection on practices.

We detected a strong reluctancy in teachers to produce meaningful reflective documentation.

Through the analysis of their beliefs, we detect the lack of a culture of documentation. Teachers perceive documentation tasks as something useless or a form of control. They do not appreciate the correlation between documentation and collaborative construction of knowledge nor between documentation and assessment.

Getting started

Getting started with the design of maker-centered learning environments can be a hard task for a novice, especially for somebody who is not comfortable with technology. The first maker-centered experience is critical, because the complexity involved in making can lead the participants to quit.

It seems to be quite effective to reduce that complexity by structuring the activity in autonomous modular units. Modular activities allow the participant to build meaningful artifacts with less complexity involved. The accomplishment of the first module enables teachers to feel more confident and motivated to build a more complex prototype combining familiar modules.

The Teaching Model

In this section we offer a description of how the teaching model generated stressing on its evolution through the 4 iterations and the definition of design principles.

The preliminary model

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 design, implement and evaluate learning environments enhanced by digital fabrication tools.

The intensive workshops and the working sessions were aimed to implement the learning environments designed during the teacher training. Each group of students and teachers participated in 3 intensive workshops during the first part of the school year and attended 8 working sessions of more product-oriented activities during the second part. The teacher training and the intensive workshops were facilitated by the researchers, the working sessions were run by the fabLAB manager.

During every implementation we made modifications to the preliminary design model based as summarised in Table 3.

Design principles

The actual teaching model is built around a set of design principles related to three different modules.

Initiation

The initiation module in an intensive three-day teacher training focused on the ludic creation of technological artifacts. The intensive format is a key point: working intensively allows teachers to get familiar with the tools and accomplish, at least, one creation task. The achievement of just one simple construction helps the teacher to get more confidence and motivation.

The initiation in the first place aims to foster a confident attitude towards the creation of technology and its creative use. Also it aims to offer a meaningful maker-centered "I can do it" experience as a way to reassure the participant that he's able to design artifacts while is acquiring a basic set of technical skills.

During the creation process, it is extremely important to provide the participants with the adequate time as well as as with enough emotional, pedagogical and technical support.

The training is based on a constructionist framework, the same that will be used for the students in the classroom. The intention is to invite the teacher to reflect on every aspect involved in maker-centered activities by living the same learning experience as their students.

The initiation aims to offer a meaningful design experience, not just a simulation. The design of a real artifact from scratch might be a hard task, but it is perfectly possible with the adequate scaffolding. The passing through struggle and frustration prompts teachers to analyse all the aspects involved in making, in order to elaborate strategies for the design and the facilitation of making-centered activities.

Therefore the initiation aims provide the teachers a set of technical skills related to computer aided design and digital fabrication tools. We recommend that teachers at this stage acquire just the basic set of technical skills they need in order to design their first simple maker-centered activity.

Training in Practice

Training in practice takes place right after the initiation, preferably at the beginning of the school year. It is divided in 8 sessions of 4 hours. During the first 2 sessions each group of teachers, the researchers and the fablab manager co-design the maker-centered learning environments that will be really implemented with students during the school year. Once the learning environments are designed students, teachers and researchers will bring the design to practice in order to getting it tested and evaluated.

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During this module, teachers are invited to acquire strategies for the facilitation of creative processes right in the classroom or the fablab, working directly with their students. Also they are invited to experiment, with the support of researchers, a non-instructive teaching style and to practice strategies for assessment of maker-cenered activities through observation.

The Education Laboratory

The education laboratory aims to be a space for reflection and experimentation around the design of active learning environment. It is conceived as an interested-based group of teachers who get together to design, make, analyse and share maker-based practices and tools.

Its main goals are: the design of learning environments; the prototyping of educational materials; the design and implementation of peer training, mentoring, learning groups; the dissemination of maker-centered practices in the school community (teachers and families) as well as in the online communities of interest.

Training in maker-centered education requires a constant effort because tools and strategies are continuously evolving with contribution of the maker community and the technological development. For this reason its implementation has to be based on permanent training and collaborative knowledge construction.

We envision the education laboratory as a repository for tools and material as well as a group of teachers, meeting on a regular base, sharing a concern for experiential education and their passion for making. The empowering effect of this kind of laboratory depends on the engagement of the stakeholder. So it should be an environment supported by the school community by providing the time and the resources as well as encouraging participation.

Conclusion

The analysis of the critical features detected during the study helped us to define a structure and a set of principles for the design of the training model, allowing its adaptation to the specific context during the 4 implementations.

In addiction to the assessment of the model and the decision making along the design process, the analysis of the critical features led us to identify a set of educational needs based on the lack of strategies showed by the stakeholders in several domains: emotional management, documentation of processes, and inquiry-based learning.

In order to disseminate maker-centered education as an opportunity for a change in teaching practices toward a constructionist approach we need to address and satisfy those educational needs. The training model we propose aims to provide teachers with deep learning co-design experiences based on experimentation, research, collaborative knowledge building between researchers and practitioners and inquiry as principle for learning design.

Deep learning co-design experiences as TDR have the potential to interact with the teachers' beliefs, generating deep changes, but the process has to be supported by strategies for emotional managing to sustain the change.

Strategies for emotional managing, are especially important in order to support the teachers to take advantage of frustration and failure as resources for learning and creation. They are required as well to build and develop an attitude of no intervention in the interaction with the students and their creative process, choosing pedagogical observation in stead of instructional intervention.

Maker-centred education as instance of experiential learning advocates for reflection on practice, collaborative knowledge construction and integrate training in the context where learning is happening, an environment preferably rich in technology. In this scenario teachers need to develop significant and useful reflexive documentation from their own practice, as well as strategies for inquiry-based learning.

Reflection on practice is a key point for professional growth as well as collaborative knowledge construction in the context where learning is happening. From this perspective is crucial to support teachers implementing technology enhanced learning environments with reflective practices that enable them to uses meaningly their practical knowledge.

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