Only For The Rich? Accessible classroom infrastructure for the maker movement

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Abstract
For the maker movement to find its way in the large-scale education, school infrastructure (un)availability is a critical factor. In this paper we present the eSIT4SIP approach; using ontology and knowledge engineering tools and concepts of “elementary activity”, “ICT educational functionality” and “instructional design patterns”, eSIT4SIP provides teachers with tools to adapt and adopt ICT-enhanced activities to their school’s existing infrastructure. We investigate the specific challenges of “craft-and-make” educational scenaria and we explore lines of further work to support teachers not only to adapt these activities to the available equipment but also to preserve the spirit and the pedagogical principles of the maker movement.

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Maker movement, school infrastructure, learning activities, instructional patterns.

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K.3.1 Computer Uses in Education; K.3.2 Computer and Information Science Education;

Introduction - Motivation
“*Education is not an affair of “telling” and being told, but an active and constructive process….. its enactment into practice requires that the school environment be*

equipped with agencies for doing, with tools and physical materials, to an extent rarely attained". [2:43]. J. Dewey's observation, old but unfortunately not outdated, resonates with the advocating of the maker movement in schools now and the constructionist approach some decades earlier [4].

Although the advantages for learning by doing or through making in STEM – but not only- are clearly emerging, the practice of these approaches is still problematic. Three obstacles are usually presented by active teachers:

- Teaching in this way is much more difficult and time-consuming (for its preparation).
- The overloaded curriculum cannot accommodate such luxuries.
- The infrastructure necessary is not available in most schools.

We would be lying if we were to dismiss the first objection. Furthermore, when it comes to maker technologies, their use often requires specialized knowledge: "*if you need specialized tools, you also need specialized knowledge. If you magically gave me a shop full of materials for electronics, CNC machine, 3D maker bot, wood shop, I would not magically transform into a super maker teacher. … This is a lot harder then (sic) hacking out a good science experiment "* [1]. However, many teachers are willing to put the extra work needed if the other two obstacles are overcome -many more than those already in the maker movement. Moreover, when the movement actually moves, sharing scenaria and activities prepared by colleagues will greatly reduce the workload.

The second objection stems from the misunderstanding that teaching is the dual of learning; that "covering the curriculum subject matter" means lecturing; that direct instruction is the only way of teaching; and that since students do not get it when they are told, they will certainly not discover it by themselves! Furthermore this obstacle, being reinforced by school's emphasis on content delivery and quantitative assessment, results in classroom mal-adaptations of making, that frequently deprive it from its intrinsic learning value [5].

The third objection is well-founded; confronting it is the subject of this paper and of our eSIT4SIP (www.eSIT4SIP.eu) project. The overwhelming majority of schools in the world are not rich; they do not have anywhere near the infrastructure needed for STEM learning in the ways of the maker movement. But even in the so-called 'developed' world most schools do not have such infrastructure in the numbers necessary for all students to be using it all the time -as distinguished from going to a special lab once a week, which is less than a tenth of the time spent for STEM is schools. And even the most privileged schools will not always have the latest technology needed for that. So is the maker movement an elitist approach just for the rich?

At the same time, more and more schools have some technology available; more and more students have access to their own ICT devices; and ICT other than the latest state-of-the-art is becoming more and more affordable. So, a very legitimate question by a willing teacher of a non-privileged school is: "can I do this with my school's current ICT infrastructure?" -where 'this' is an enviably effective craft-and-maker learning scenario.

Making electronic textile designs - Example

"To create their electronic textiles, students design a functional circuit blueprint using pencil and paper, craft their objects using felt materials, stitch the circuits to connect the LED lights and write the code to control them" (Example of activity taken from Kafai et al [5])

Instructional Pattern: Students individually, construct a hybrid (physical - digital) object with materials specified by the teacher.

Learning objectives: (Inferred by the analysis of the paper): To explore the use of circuits and principles of electricity, to apply programming knowledge, to understand how things work, to promote artistic expression.

Infrastructure: LilyPad Arduino; Paper and pen circuit blueprints; Conductive thread; Felt material; Computer lab.

If a scenario dictates for the students to "take this picture, frame it, and hang in on the class wall using a hammer and a nail provided", it does not take a very innovative teacher to replace the hammer with a stone and find an old throw-away nail somewhere, if the tools specified are not available; depending on the situation they might also just blue-tag the unframed picture on the wall. What are equivalent substitutions in the digital world? And how can we point them out to teachers (semi-)automatically? Such are the questions we deal with in eSIT4SIP. We also hope that by facilitating a possible solution to infrastructure problems, we are paving the way for a reflection that will advance our thinking and action on the first two problems (i.e time and curriculum).

eSIT4SIP Approach and Methodology

eSIT4SIP (Empowering the School IT infrastructures for the implementation of Sustainable Instructional Patterns) facilitates the implementation of ICT-enhanced novel teaching practices. Because designing a good scenario takes a lot of time (not to mention knowledge, skills and creativity) teachers often try to implement in their classrooms existing scenaria taken from repositories. While reuse is fundamental to productivity, two dangers lurk in blind copying: infeasibility ("I do not have the required ICT, time or skills") and irrelevancy ("a very good scenario that did not serve my instructional goals"). Enter tinkering and adaptation. How do we facilitate ICT usage tinkering for intelligent scenario adaptation?

In eSIT4SIP we analyzed a corpus of good educational scenaria and produced a methodology, a set of examples, a concept ontology (taxonomy) and a Knowledge Base System for ICT-in-school-education tinkering and adaptation techniques. Table 1 presents the basic system concepts. The goal is to help teachers (a) design their lessons from the viewpoint of allocation of the necessary ICT facilities while matching the available resources with the intended learning designs, and (b) evaluate the feasibility of carrying out particular types of learning activities given the available school ICT facilities. The supporting decision-making functionalities constitutes one of the main contributions of eSIT4SIP.

Educational Scenario	<u>involves</u> Instructional Design Pattern(s) <u>is applicable to</u> (one or more) Educational Context(s) <u>serves</u> Learning Goal(s) <u>uses</u> ICT in specific way(s) <u>consists of</u> (or: is analyzed into, or: includes) Elementary (ICT) Activities
Educational Context	<u>Student attributes</u> (age, background, special needs/skills…) <u>Content</u> (subject, previous knowledge, language…) <u>Organization</u> (school, number of students, f2f/distance …)
Elementary (ICT-enhanced) activity, or **Microactivity**, or Simple ICT Use	<u>involves</u> specified use of ICT <u>for</u> Specified hardware/software e.g. Take a picture with a phone, Draw an equilateral triangle with GeoGebra etc
Instructional Approach (**aka Instructional**	e.g. Use "Learning by teaching" IDP to increase student's sense of responsibility and overcome

Making electronic paper designs – eSIT4SIP approach
Students create paper designs (drawings, or even texts) design a functional circuit blueprint with an electric pen, integrate in their design led lights.

Instructional Pattern: Students individually, construct a physical object with materials specified by the teacher.

Infrastructure: electric pen, batteries, led lights, paper, crocodile clips, batteries

Learning objectives: To explore the use of circuits and principles of electricity, to understand how things work, to promote artistic expression and connect it to STEM.

Design Pattern (IDP) when viewed in the context of Learning Design) Serves teaching meta-goals; is orthogonal to learning goals	"why do I care" attitude. Use "Inverted classroom" IDP to deal with lecture time inadequacy. Use "Students create content" IDP to create sense of ownership in students and to allow peer assessment.
ICT Affordance (related to **Educational ICT Functionality**)	An ICT Affordance allows an Educational ICT Functionality e.g. *a web site has the ICT affordance to store a file and make it available to many users, which allows the Educational ICT Functionality to make a multimedia learning object available for students to use within an educationally appropriate time window*.

Table 1: eSIT4SIP Conceptual Design

A Knowledge-Base of Learning Scenarios to Support Maker movement in Schools?

Currently, the eSIT4SIP methodology is neutral: the scenaria analyzed come from all learning theories (although, to be frank, behaviorism is underrepresented); educational context and learning goals relate to all pedagogical approaches; elementary activities are devoid of learning goals; it is through Instructional Design Patterns that the eSIT4SIP Knowledge Base connects to pedagogical approaches. Craft and make activities do not belong to a single pedagogy: following explicit, direct and detailed instructions for making an object is clearly behaviorist; freedom to choose what is to be made, to explore method to be used for making, and the use of non-prescriptive instructions lead to constructionist pedagogy; while work in teams, whether in making, tinkering or peer evaluating add the social dynamics of learning.

We can have various instructional patterns in the craft-make movement. They may vary in the class organization (team formation), in the freedom of the student(s) as to what they are making, in the freedom of the student(s) as to how they are making it. Depending on the learning goal(s) and the educational context, the teacher can choose the specific craft-make instructional pattern. A basic question that arises here is: If some part of the construction is replaced by (a) a simulation (b) digital instead of physical objects (c) alternative physical objects, which learning goals can still be served? Furthermore, are these learning goals relevant to the maker culture?

In the example analyzed in the sidebars, we attempted to explore some of these questions (using the main aspects from the conceptual design at this stage): From the initial activity, which involved the construction of e-textile designs, we considered an alternative for a context where LilyPad Arduino and felt material are not available. The proposed alternative involves replacing the felt material with paper and omitting LilyPad Arduino. The affordance of the paper can be considered similar to that of the felt material in that it allows artistic expression and integration of the pen and paper drawn circuits. The affordances of the pen and paper drawn circuits are not discussed here because they are included in the transformed scenario. The initial workshop was implemented in the context of workshops carried out in a science museum which was partnered with a school. In the proposed alternative the context can be a science classroom or vocational education. The main elementary activity we discuss here is the use of circuits with felt or with paper. Although the final construct is not that sophisticated and the conceptualization of electronics involves different aspects when fabric is used (for details see [3]), the result seems to serve the making approach and the initial intention of combining STEM with artistic expression. Furthermore, if programming was the central focus of the educational scenario then other alternatives should be considered.

Concluding Remarks – Further work

The rationale presented here and the example we analyzed show that the knowledge-base of eSIT4SIP has the potential to become a valuable tool in supporting teachers to explore the available technological resources and engage their students in makers' movement projects. Further work is needed in this dimension. A first step would be to populate the knowledge base with scenaria from the maker movement in formal and non-formal learning settings. This will allow us to investigate the possibility of producing a subset of instructional patterns relevant to the "craft and make" activities, which will not only make use of available infrastructure in schools but they will also resonate with the spirit and the pedagogical approach of the maker movement.

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