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Smart material interfaces for education ☆

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ABSTRACT

This paper describes an experience, held with a class of primary school children, aimed to introduce a novel educational topic, the smart materials, and the interfaces built with them (Smart Material Interfaces). The pupils were guided along a multidisciplinary path in which traditional and innovative teaching methods were composed for educating while engaging the children. It led to the creation of 6 automated puppet plays focused on the themes of environmental awareness as a result. In this process, storytelling and visual programming acted as powerful means for merging different educational concepts and techniques. The data collected through the direct observation and the questionnaires indicate that the experience was perceived as positive and interesting. The post evaluation, held some months later, revealed skills and knowledge improvements in all the areas involved by the multidisciplinary experience.

1. Motivation

Educators should be able to offer up-to-date educational paths capable of integrating the novelties of science and technology with the engagement of the pupils for improved learning. Smart materials represent a novel and interesting technological topic to teach and learn. They can change their physical properties (e.g. colour, shape, and so forth) and they can be manipulated and controlled through different hardware platforms (e.g. Arduino) for the creation of interesting and engaging interfaces (i.e., Smart Material Interfaces, SMIs [1]). The interest of this exploratory study lays in the introduction of these complex technology topics in the Primary School and on the design of an interdisciplinary educational path supporting this goal. For reaching this goal the educational experience included scientific, technical, artistic topics and literacy skills, meant for engaging the children while educating them. It is important to underline that the topics that were introduced for stimulating the interest for the smart materials worked not just as a means but they were themselves a focus of interest. Storytelling, which has long been recognised as a powerful means for engaging children in educational contexts, was used in this work as a glue for connecting the different educational topics. Storytelling provided an overall goal to the students' work: the creation of stories focused on environmental awareness themes. In this experience the children were challenged in the creation of origami[1] models as elements of a story. These elements were augmented with smart materials and programmed to act as the stories created by the children prescribed. A Scratch[2] based environment (S4A[3]) was used as mediating tool for translating the narrative structures into

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[1] The Japanese art of folding paper into shapes and figures.
[2] Scratch: visual programming language http://scratch.mit.edu.
[3] Realised in the context of the EU project Citilab http://seaside.citilab.eu.

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Table 1
A short description, time line and focus of attention of each phase.

Session	Lesson description	Survey	Main focus	Length
1	We taught the children how to make plain origami models and create stories with them		Origami	1 half-day
2	We introduced SMs and SMIs with several small examples	First	SMs and SMIs	1 half-day
3	The children modified the stories for adding smart materials to origami		Narration, SMs and SMIs	1 half-day
4	The children broke down the stories into narrative blocks, introduction to programming symbols		Narrative blocks	1 half-day
5	We explained the basics of programming in S4A and taught how to create origami animations on Arduino from S4A. We asked the children to program their stories		S4A, Arduino	1 day
6	We prepared the setup for the final cardboard theatre representations		S4A, Arduino	1 half-day
7	The children saw the realisation of their work and filled in the second questionnaire	Second	Grading	1 half-day
8	We evaluated the educational impact after the end of the experience	Final	Evaluation	1 day

programming blocks. It connected the models to an Arduino board[4] for triggering the actions of the associated smart materials. The Arduino-controlled stories were finally represented in cardboard theatres. The data collected during and after the experience indicate that the educational path was perceived as engaging [2] and that the children improved their skills and knowledge in all the areas involved by the multidisciplinary experience.

2. Related works

Smart materials (SMs) are a category of materials that can change a physical property in a controlled way. They are already embedded in electronics and products of everyday use (e.g. darkening sunglasses, glasses that remember their shape after deformation). Recently have they started to be used also in the creation of do-it-yourself projects. SMs represent an interesting educational topic. Their use as components of interfaces made of physical objects can give a strong boost for attracting the interest of younger minds towards the knowledge of their properties. Physical interfaces, made of objects belonging to the everyday experience, instead of traditional ones based on the WIMP paradigm[5] seem to be very attractive for children. Sun and Han [3] tested different kinds of input interfaces, such as keyboards, aluminium foil pads and bananas. Even though the bananas scored as the worst in performance, they were also the best for engagement and enjoyment. In this work we refer to interfaces making use of smart materials as to Smart Material Interfaces [4]. Boden et al. [5] used just paper, in the artistic shape of origami, to support augmented play and learning for children. Others in the past have tried to couple new materials with toys, for example in [6] textile is described as a user interface for an interactive toy that responds to events by changing patterns. Storytelling represents another interesting means for education. As we know from [7], “many studies […] suggest that storytelling (meant as the capacity to listen, tell, and reflect on stories) is an extremely important developmental area for children, promoting a wide spectrum of cognitive functions and skills: expression, communication, recognition, recall, interpretation, analysis, and synthesis”. Some experiences related to storytelling take advantage of visual programming languages. Different researchers have designed and experimented with visual paradigms for children, with the goal of teaching them to program. Alice [8], one of the most famous languages, allows children to program a 3D environment using a drag and drop style. Looking Glass [9], a successor, introduces children to programming by coupling 3D and storytelling. Scratch is a block based graphical programming language that permits children to build 2D stories and games. Blockly [10] is a similar visual programming editor (usable via browser) that allows children to learn programming while playing. Other educational experiences couple storytelling with tangible technologies. Jacoby and Buechley [11] taught children about circuitry and conductivity with an interesting kit (StoryClip) to produce drawings that they could bring to life with their recorded speech, by enhancing traditional paper with augmented properties. Our educational project lays at the intersection of all these topics, taking advantage of augmented physical objects and visual programming paradigms for building an engaging storytelling experience and, ultimately, for augmenting the children's skills and knowledge.

3. Teaching process

For this experience we used various materials, hardware and software. The smart materials used were of two kinds, the choice based on the most aesthetic and interesting properties: changing shape (Shape Memory Alloy, SMA) and colours (thermochromic paints). The *thermochromic* paint has a thermic threshold, once it is reached it becomes transparent. We applied resistive wire to the back of the paper to reach the needed temperature gradient, this allowed us to “switch the colour on or off”. Among the *SMAs* we employed NiTiNOL. It can contract once it reaches its temperature threshold. We created actuators with it to be applied to the children's creations. To control them we used Arduino and homemade circuits connected to the animated origami models. For the experience we used S4A, a modified version of Scratch. S4A allows the control of actuators through Arduino using a Scratch-like language.

[4] Arduino is an open hardware platform http://arduino.cc
[5] W.I.M.P. paradigm: acronym for Windows Icons Mouse and Pointer interaction paradigm, by Merzouga Wilberts in 1980.