EDUWEAR: DESIGNING SMART TEXTILES FOR PLAYFUL LEARNING

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Abstract
In this paper we describe the EduWear construction kit that allows children and young people to both interact with new ‘intelligent’ materials and understand their technological background. Based on constructionism we argue that children and young people learn best when designing artefacts themselves. The kit consists of programming software, smart textiles, sensors, actuators and micro-controllers that enable learners to actually make ‘smart fashion’ artefacts. Since fashion is highly valued in youth culture the kit is likely to attract children and young people, even more when considering smart textiles and wearables as somewhat “magic.” Moreover, they comprise forms of expression, communication; hence foster awareness of body, movement and clothes. In this paper we introduce the components of the kit and give examples of young learners’ projects. We also put forward a pedagogic concept that we consider very important. Finally, we present our evaluation results of workshops in different countries, settings and age groups.

Introduction
The European research project EduWear aims at developing a construction kit for smart textiles to enable children and young people develop their own “wearables.” The environments in which this kit is used are intended to afford participants the opportunities to engage in Constructionist learning experiences.

Constructionist Learning
The principles of constructionism underpin the design of the learning environment, the pedagogical approach and how the computational materials are used within the EduWear project.

Constructionism, “the N word as opposed to the V word — shares constructivism’s connotation of learning as ‘building knowledge structures’”
(Papert & Harel, 1991). So rather than conceptualising learners as vessels into which knowledge must be instilled, constructionism sees learners as active builders of their own knowledge and asserts that people learn with particular effectiveness when they are engaged in constructing personally meaningful artefacts. However, constructionists would argue that learning “happens especially felicitously in a context where the learner is consciously engaged in the construction of a public entity whether it’s a sand castle on the beach or a theory of the universe” (Papert & Harel, 1991). In our current digitised society, these artefacts can include designing and building computer programs, animations or robots. These artefacts are “objects to think with” (Papert, 1980; Turkle, 1995) and a means by which others can become involved in the thinking process while the learner’s thinking benefits from the multiple views and discussions. The tools and materials used influence the nature of the artefact and therefore the thinking. There is consequently an interrelatedness of a symbiotic nature that exists between learners, the materials they use and the constructed artefact that they create which becomes their “object to think with.”

The EduWear project emphasises digital technologies both because they are prominent in contemporary culture, and therefore important from a skills-development perspective, but even more importantly because the properties of computational materials characterise general phenomena that are worth knowing about. Learning about computation develops a basis for thinking about the world and how it works. Using tangibles and wearables (especially smart textiles) in particular open up opportunities for haptic, tactile and aesthetic experiences, thus a wider range of learner types can be included. Due to the rich history of textiles, their combination with digital technology will foster a new perspective, from which textiles and their traditional symbolic and emotional meaning can be viewed. As an advanced technical material it should attract the interest of both girls and boys.

Related Work

Construction Kits

“Construction kits” are tools often used in constructionist learning environments and can be described as “systems that engage kids in designing and creating things, sometimes on the screen, sometimes in the physical world, sometimes both” (Resnick, Silverman, 2005). As that is a very wide definition we will refer to construction kits here as tools that allow children to create computational artefacts and typically combine physical materials and a part on screen.

An important design criterion for construction kits is that they allow an easy entry for novices but can be used for advanced projects by expert users as well. In
Papert’s words, they should provide “a low floor and high ceiling.” Resnick and Silverman (2005) added designing for “wide walls” in order to allow users build a wide range of applications.

Many early construction kits were based on Papert’s Logo language that allows programming with a set of easy commands (e.g., “a,” “on,” or “beep”). From the original Programmable Logo Brick to the commercially successful Lego Mindstorms (Martin et al., 2000) changes occurred with regard to the programming languages that were used. Visual Programming Languages (VPL) were developed as an alternative approach to enable children to program. Later versions of the Lego Mindstorms for example shipped with the “Robotic Invention System” that deploys a “block” metaphor (Begel, 1996). With this type of programming interface instead of writing a Logo-like dialect herself the learner can drag and drop graphical representations of Logo commands on a canvas to create her program.

Currently we also see a development on the physical side of construction kits towards using novel smart materials (Eisenberg, 2005), while also exploring new fields and target groups. A great example is Buechley’s kit (Buechley et al., 2008) for e-textiles and wearables that consists of a micro-controller, sensors and actuators that are easily attachable to clothes by sewing with conductive yarn. The field of textiles can attract different groups (e.g., teenage girls that may find robotics less appealing).

**Pedagogic Concepts**

The Constructionist approach is based on an intimate connection between knowledge and activity. Therefore the selection of specific building materials is an important starting point enabling Constructionist learning. Traditional classroom settings, however, are generally not conducive to the activity of building and to encouraging collaboration and the free exchange of ideas. Environments more familiar to artists, architects and craftspeople are better suited. In these Atelier style environments, participants engage with complex, open-ended problems over a protracted length of time. They are encouraged to collaborate, they address a heterogeneity of issues and reflection is explicitly incorporated (Cavallo, 2000; Kuhn, 2001). Error! Reference source not found.

A primary goal of the Atelier workshop is to bring together a community of learners... At the Atelier event, they collaborate, communicate, learn, and reflect by being together. They combine the new concepts they have explored with their individual and collective knowledges, experiences, and stories; they weave a tapestry from the colorful threads of their diverse backgrounds and interests. They engage their collective creative potential and their understandings of their environment. (Ueda, 1999)
The Empowering Minds\(^1\) immersive Atelier style workshops, from which we draw our inspirations for the EduWear workshop model, were and continue to be learner-centred ensuring all participants are treated in a caring and respectful way. Every effort is made to focus on each individual’s needs and interests to support them in becoming self-determined learners. Decisions are not imposed on the group nor are they told what to do, the learners make their own choices which has been demonstrated (Butler, 2004; Butler et al., 2000; Butler & Strohecker, 2005) “works wonders in terms of creativity and morale” (Haase, 2000). The immersive Atelier workshop approach is a process common to other projects which Papert has been involved with including Project Highlight at Boston’s Hennigan School during the mid-eighties (Harel & Papert, 1991), the Omar Dengo Foundation’s work in Costa Rica\(^2\) and Project Lighthouse in Thailand (Cavallo, 2000).

This immersive Atelier style model which we built upon and develop in the EduWear workshops is discussed in greater depth later in this paper.

**EduWear Approach**

The basic essentials of the EduWear approach are the construction kit and the pedagogic concept which informs the design of an appropriate learning environment for the kit.

**The EduWear Kit and Technology**

The EduWear construction kit consists of a programming language, microcontroller boards, sensors and actuators, as well as connectors for building circuits. These components are enriched by non-conductive textiles and other handicraft materials, so that the users can also integrate smart textiles into their own garments. The target group for the kit is children and teenagers between 10 and 14 years old.

**The controller board.** A microcontroller to be used with smart textiles needs to be small in size, lightweight and have low power consumption. On the other hand if such a controller is to be used for educational purposes it needs to be affordable, robust and manageable by children and young people. As a consequence we have chosen the open-source architecture “Arduino” as the basis for our development.

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\(^1\) [http://empoweringminds.spd.dcu.ie](http://empoweringminds.spd.dcu.ie)

\(^2\) [http://www.fod.ac.cr/](http://www.fod.ac.cr/)
Arduino consists of microcontroller-boards, a programming environment and a community of users and developers. The key concept of Arduino is bringing the idea of open-source software to hardware, reducing complexity for the user instead of hiding it and creating a cheap and easy-to-get system, whose development is fostered by a community (Mellis et al., 2007). The Arduino board architecture uses “Atmel Atmega” chips. The Arduino boards are programmed over a serial or USB port. Since the Atmel chip holds a bootloader, an external programming device is not needed.

For the EduWear construction kit, we have developed a prototype for a controller board, which is distributed into three single components. As not all components have to be mounted to a textile, one can save space and only mount what is necessary. The components are a “programmer board” for establishing a serial connection to the computer while programming the chip, the “power board” to run the main board with different voltages, and the “main board” with an Atmel ATMEGA 8 Microchip. This chip has an eight kilobyte flash memory, 14 digital in- and outputs and 6 analogue inputs. Only the main board has to be mounted to the textile. It is optional whether to mount the power board or not, the “programmer board” is not needed on the textile.

Following a participatory design approach, we have been organising workshops since the beginning of the EduWear project. Therefore, a great amount of reliable boards has been needed from the beginning. As the prototypes cannot fulfill these requirements yet, Arduino Diecemilla or NG and recently also the Arduino LilyPad boards have been used in the EduWear workshops. The latter board is especially made for usage with textile, as they are very small and provide connections for conductive yarn instead of cables (Buechley et al., 2000).

**Programming.** The Arduino boards are programmed with the textual language Arduino, which is based on Wiring\(^3\) and Processing\(^4\), and which is often used by students in the design and arts field for creating interactive prototypes. The language is technically a simplified C++. However, it has been found that this language is too complicated for children to learn and apply it within a few days. Therefore, we have developed a VPL we call “Amici.” Amici is related to LogoBlocks (Begel, 1996): An iconic “block” represents a program command and can be dragged with the mouse so that children create their programs by aligning the blocks. The system then translates the block program into textual code.

Children can see this code on another layer and get inside into professional

\(^3\) [http://wiring.org.co/](http://wiring.org.co/)

\(^4\) [http://processing.org/](http://processing.org/)
programming, but do not have to understand all of it in order to create their own programs. Besides the Arduino code layer, the Amici VPL integrates the Virtual Lab where children can publish and share their projects online.

Through integrating sharing into the VPL children and young people can refer to other people’s projects when they get stuck while programming. Furthermore they can add “tags” to the blocks they are using, creating their own annotations through the process.

**Textiles, sensors, actuators and connectors.** In order to construct physically interactive applications, the EduWear construction kit provides sensors, actuators and connectors (see Figure 1). Some components are fully textile, while others have only a textile basis integrating common technical components.

Pure textile components are for instance stretch sensors or push switches. Stretch sensors are knitted material with conductive thread to measure the amount of stretching (as the resistance varies). Push switches consist of two conductive layers (e.g., conductive yarn or fabric), which are separated by insulating material (e.g., foam) so that a circuit is closed whenever the switch is being pressed.

Combining resistors with sensors and connecting them appropriately to the board is very fiddly for children, as it requires neat working in order to achieve reliable connections. Therefore, we have created textile patches, into which the sensors or LEDs and resistors are already integrated.

To integrate sensors and actuators into garments, often long distances have to be covered (e.g., the arm). For instance, a sensor requires three different paths (ground, power, input), which are not to touch each other. This imposes further challenges upon children. As a consequence, we provide textile buses with the kit. This should make things simpler when designing a project as circuit paths of conductive yarn are integrated into textile material and can be used without having to sew them.
Project Examples
The projects children create involve all kinds of garments: shoes that count steps, gloves which react on gestures with different lightning, shirts that light up in the dark, caps with built in ventilation to respond to high temperature — to name only a few. An interesting example children created was the “Fitness Shirt” (see Figure 2): whenever the wearer’s elbows touch the waist, LEDs flash up. The movement was meant as a fitness exercise and the LEDs to indicate whether the wearer performed the exercise correctly.
Pedagogic Concept
As discussed earlier the pedagogic approach adopted in the EduWear workshops is rooted in constructionism which sees learners as active builders of their own knowledge. To facilitate learners constructing personally meaningful artefacts (Papert, 1991 p.1) that can be shown and discussed with others the EduWear group designed immersive Atelier style learning environments. EduWear workshops have many of the key features of an Atelier style of working as identified by Kuhn (2001) including:

- participants engage with complex open-ended problems over a protracted length of time
- collaboration is encouraged
- reflection is explicitly incorporated
- a heterogeneity of issues are addressed.

Consistent with the Atelier approach, as projects are being developed there is constant ongoing discussion and critique of the work as ideas and constructions grow and change. A special strength of the Atelier style “is its ability to support multidisciplinary and integrative education. The studio can act as a forum for debate and discussion of a wide variety of issues” (Kuhn, 2000). Great efforts are made to develop an atmosphere of trust and acceptance among the group so that people feel comfortable expressing their opinions and understand that dissension and disagreement are accepted. The EduWear materials and the Atelier-style learning approach “encourage dialogue, self-expression, community and reflection” (Ueda, 1999). People are learning through experience — learning by doing. Working in an immersive learning environment with the set of expressive computational materials in the EduWear toolkit affords learners an opportunity where they are responsible for the conception, design, construction, programming and debugging of an artefact using smart textiles. More importantly, throughout the workshops learners are reflecting on what they are doing and beginning the process of “learning about learning”.

First Results
Since spring 2007, the participating institutions in Germany, Sweden, Slovakia, Ireland and Hungary have run about 13 workshops with approximately 150 children participating in total. As we follow a participatory design approach, the experiences from the workshops have immediately influenced the ongoing development of the construction kit.
Pedagogical and Gender Aspects
The EduWear concept works well; most of the EduWear workshops have been very successful according to reports and questionnaires. The wide range of materials invite participants to create meaningful projects and many participants are interested in working with the kit in the future. Participants understand the idea behind smart textiles and see a lot of potential for the use of the kit. However, this kind of work also requires patience, e.g. short-circuits and breaking patches can cause frustration. Technology is still predominant rather than design, but children also care for aesthetics when supported. Some even make attempts to design and decorate their projects nicely, without any guidance while others neglected aesthetics completely. Furthermore, the LilyPad board has proved to be more aesthetically pleasing than the previous boards.

Girls are sometimes not very keen on programming, preferring to spend their time designing and constructing the artefacts. Boys in some cases do not like to work with the needle at first. However, motivated by their project goals they do engage in sewing. In order to support textile aesthetics future workshops are going to focus more on the topic of fashion whereby textile teachers and designers are consulted to take part.

Both girls and boys take part in workshops, but girls are often less represented than boys. We believe that the practice of making announcements of workshops in the press and at institutions where technology seems to be predominant needs to be altered.

Material of the EduWear Construction Kit
Children use both textile patches and un-patched separate sensors and actuators. Sometimes ready-made ones provided with resistors and connectors are preferred (e.g., in Germany). In Sweden and Slovakia children preferred their own creations. Textile switches are sometimes difficult to use as contacts are sensitive and might ‘confuse’ the board and therefore frustrate children as it was evident in Slovakia. Children also created their own switches using non-conductive thread and conductive material (e.g., knitted stainless steel copper and polyester/copper). Overall, data buses widely deployed and prove to be very useful.

For some children, the Arduino board is too small and unreliable and might lead to frustration. As for the connection of wires and yarn to the board children have overcome difficulties by creating clips, pins and rings, e.g., if they want to create a multiple LED display consisting of many, e.g., 14, LEDs. They have produced custom made items, e.g. use office metal clips as connectors or metal rings to connect conductive yarn to a cable. LEDs have been the most popular actuators in many workshops and tutors from Ireland recommend having much more of them available in the future. Irish participants also appreciate crocodile leads as they
allow them to quickly put circuits together and achieve success before getting frustrated.

**Experiences with Programming**
Introducing Amici at the beginning of a workshop and teaching children how to program has been extremely helpful when participants came to programming their own projects. Other introductory tasks such as how to connect the boards to a computer and how to upload programs proved to be helpful at later stages of the workshop. Children often cope with the interface by using basic examples that are provided. The programming guide is referred to regularly by participants. Older students are able to work alone most of the time while younger children generally need more support, especially when problems occur (e.g., short-circuits, unstable connections, misconceptions of programming elements). Others forget to choose ports before uploading their programs or mix up sensors and actuators or do not understand the difference between digital and analogue ports. At the beginning, most of them need help in connecting analogue sensors to the board and do not engage proactively in debugging, but wait for a tutor instead. Overall, tutors report that programming has been a rather uncomplicated part of the workshops. The tutors of the Hungarian workshops report even no problems at all with programming.

**Summary and Future Work**
Influenced by constructionist learning theory, we have developed a construction kit for smart textiles. The kit comprises a programming environment, microcontroller boards, as well as sensors, actuators and connectors which are either completely textile or integrated into textiles. The kit is embedded into a pedagogic concept, which is related to the Atelier-style learning approach, aiming at active and reflective learning experiences with the kit. Our results from the workshops reveal rich learning experiences, e.g., by working with textiles or computer programming and by overcoming the challenges that occur.

Whether the EduWear kit will be commercially produced is still an open-ended question. However, reliable boards as well as basic textile material (e.g., conductive thread) are available on the market (Buechley et al., 2008). With EduWear, we provide the VPL Amici, which is available for download\(^5\) and compatible with all Arduino boards, as well as the pedagogic concept. Thus, the EduWear approach can be spread and adopted by other parties. In future

\(^5\) [http://www.dimeb.de/eduwear](http://www.dimeb.de/eduwear)
workshops we will emphasise more on fashion and design aspects to increase especially the girls’ interest in the EduWear smart textile construction kit.

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References


