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Smart Textile objects and conductible ink as a context for arts based teaching and learning of computational thinking at primary school

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ABSTRACT
The shaping of Smart Textile artefacts brings together a variety of learning activities, such as imagining, designing, drawing, constructing, wiring, programming, controlling, testing, debugging and presenting self-made, invented media objects, realized in project- and team based arrangements. A variety of human senses are addressed when pupils develop and sketch their project ideas to be realized. In the paper, we discuss the topic of self-made Smart Textile objects as a learning content for primary school level, towards the development of curriculum modules for project learning in the classroom as well as teacher training. It was developed in the 'Teachers Aids on Creating Contents for Learning Environments' TACCLE3 coding project.

CCS Concepts
• **Software →Programming Environments.**

Keywords
Smart textile; wearables, tangible media; art and design based learning; physical computing; contextualized learning; cross-disciplinary learning.

1. INTRODUCTION
TACCLE 3 Coding [1] aims to encourage and support teachers to introduce coding, programming and computational thinking as part of the curriculum in the 4 - 14 classroom to better equip pupils to develop the skills needed by the European labour market. It aims to broaden teachers' digital skills base and enhance their professional competence and show how entrepreneurial skills can be developed and integrated with programming skills. The project intends to stimulate a positive attitude towards STEM with young children. In the paper, more playful, visual and arts-based modules to teaching and learning about computational modeling and thinking are introduced.

As 'software takes command' [2], computational thinking is identified to be an important learning goal for curricula to teach coding. It is part of the new curricula developed in some countries, such as Wales, U.K. and Estonia. In Germany, there are some initiatives stressing the importance for children to learn programming at primary school level [3] [4], but it is not a part of the school curricula. Computational thinking includes the development of algorithms, the controlling and debugging of things, the use of logic as well as "a problem-solving process, that includes (but is not limited to) the following characteristics, defined for K-12 education by The International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA):

- Formulating problems in a way that enables us to use a computer and other tools to help solve them.
- Logically organizing and analyzing data
- Representing data through abstractions such as models and simulations
- Automating solutions through algorithmic thinking (a series of ordered steps)

- Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources
- Generalizing and transferring this problem solving process to a wide variety of problems." According to the International Society for Technology in Education (ISTE) and the Computer Science Teachers Association (CSTA), the skills required "are supported and enhanced by a number of dispositions or attitudes that are essential dimensions of CT", including
- Confidence in dealing with complexity
- Persistence in working with difficult problems
- Tolerance for ambiguity
- The ability to deal with open ended problems
- The ability to communicate and work with others to achieve a common goal or solution", as given in the Operational Definition of Computational Thinking for K–12 Education [5].

Coding is promoted to be an important skill for the 21C by the European Commission as well. Kafai and Burke (2014) [6] stressed the importance of children to learn programming in the context of participation and connected communities. Contexts to teach coding in an adequate way to primary school children are rarely known by current primary school teachers, and not part of teacher training in Germany yet. Furthermore, teachers are not aware they already code and program in their daily practices without knowing. In the framework of the TACCLE3 coding Erasmus+ project [7], materials for teachers to facilitate teaching computational thinking are developed and delivered online in a downloadable resource kit.

To make the abstract learning contents of coding more graspable and usable for teachers at primary school level, the concepts are linked to imagination and phantasies of young children, who can invent and realize their own project ideas to be developed by the learners themselves. The latter is done in project based learning scenarios, using embedded sensor- and actuator-based systems, based on the Arduino LilyPad technology, extended by a visual interface to facilitate programming using icons in free a drag and drop environment (amici) [8]. The technology chosen opens up to link the ideas and imagination to computational thinking and acting through more arts- and design-based processes. Examples of smart textile projects (and the sketching of electronic circuits) are presented and discussed. At KIT, contexts and activities for teaching and learning about coding by designing individual smart textile environments are developed in the framework of the TACCLE 3 project. In the following modules for learning activities to be used for teaching coding in an arts and design based, playful and experiential way at primary school level are introduced. Developing algorithms, programming and controlling things is no longer a learning content limited to be taught in computer science classes only. The blurring of boundaries of diverse school subjects taught separated from one another can be resolved introducing the context of smart textile and wearable computing. In terms of curricula, smart textile and *wearables* link subjects such as arts, design, textile, computer science, technology and electronic engineering. Not only at primary school level, smart textile serves as a context for physical computing, which allows for making the abstract notion of programming algorithms, controlling and debugging things tangible and graspable for children and young people.

In the paper, smart textile is presented as a creative environment for learning, linking the creations of aesthetic processes to computational thinking and acting. Modules for primary teacher training developed in the TACCLE3 coding project are introduced, and discussed. In conclusion, the potential of tools and media developed are presented.

2. SMART TEXTILE AS A CREATIVE ENVIRONMENT FOR LEARNING AT PRIMARY SCHOOL LEVEL

Why should school teachers be interested in Smart textile, especially if they are not admitted to either textiles, fashion or technology? This question will be answered discussing potentials opening up for learning through designing media objects. Interactive textiles, which are also referred to as 'smart textiles' or 'wearables', represent a current generation of clothes and accessories with embedded microcomputers and offer various possibilities of creatively dealing with so-called 'intelligent media', and intelligent in this case refers to their ability to perceive their environment by means of programmed micro-sensors. The system, worn on the body, can respond with behavior programmed by the children themselves. They manipulate and change technology. Using e.g. conductive yarn (as connector), sensors, motors, LED lights as well as sewable circuit boards (Arduino LilyPad introduced by Buechley), smart textiles create a link between sensual-haptic materials, precise computer control, and creative concepts. New interfaces – sewed, woven or stitched – can be experienced between body, clothing, and the environment. It can be stitched together with conductive thread to create interactive garments and accessories. In conjunction with the open-source Arduino technology, they open up opportunities for cross- disciplinary teaching of the subjects of art, design, computer science and music, for example to address learning in the context of storytelling wearables [9], wearable music [10] or sounding artifacts [11]. The Arduino LilyPad technology consists of hard components as well as a programming interface which can be connected to an icon based interface to be used by younger children at primary school level. The LilyPad can "sense information about the environment using inputs like light and temperature sensors and can act on the environment with outputs like LED lights, vibrator motors, and speakers." [12]. Kafai et al. [13] highlighted the LilyPad Arduino kit being a shapable set of technology, bringing together crafting, design and technology, supporting individual projects, beyond a specific aesthetic like the 'pink painted' application for girls. The Arduino starter kit *c*ombines craft, electronics, and programming. Children and adults of all ages interested in interactive toys, smart accessories, or light-up fashions can develop their own project according to their imagination. Pupils play with the components and learn to sew, program, and design circuits along the way. It is a technology for all ages and a way to introduce pupils including those who are less interested in engineering, e.g. girls. The combining of art and design driven aspects with learning and technology, is expected to trigger identification with a project and a deeper interest and understanding of technology. As experienced in the junior high school classroom, young people are highly motivated to develop and run their interactive projects [14, 15]. An art- and design-based learning approach to curriculum development for classroom sessions.

2.1 Curriculum modules for primary school teacher training

The learning activities developed include a teacher training, as well as a tutorial for beginners to programming, which introduces the teacher both to the handling of the LilyPad Arduino hardware and to the application of the amici user interface and can be used as instructions for teaching processes related to interactive clothing. Also the development of creative themes is addressed, to support imagination and self-initiated learning. The teacher training is based on the modules identified to develop a project. The teachers get familiar with the hardware, such as the electronic components, main board, connectors (including unusual wires made of ink or yarn) and sensors and actuators. The teachers use the same modules for project based learning with physical computing as the school kids in hands-on workshops.

2.2 Modules for project-based learning with Smart Textiles

Since, however, the handling of the software and hardware used in the project is documented only insufficiently in Germany, it was decided to write down in a structured way the experiences gained. Although the resultant tutorial does not claim to discuss all software and hardware issues, relevant problems need to be explained in detail. The tutorial was developed on the basis of the EduWear manual compiled by the "Digital media in Education (dimeb)" research group of the University of Bremen [16]. The following lesson plans for classroom sessions are linked to each other and based on one another. They form the teaching units on developing sensor and actuator based systems'/'Developing a project with Arduino LilyPad and AMICI software:

Module 1 Getting familiar with hardware

This module is part of a series of lesson plans to introduce children (from grade 5 up) to smart textile objects, based and the programming of sensors and actuators set up in an electronic circuit. After the series of lessons 1- 6, the learners will be able to develop, connect and program a sensor and actuator based interactive system and contextualize it in a project. Also there a lessons to introduce the development of electronic circuits though painting connectors (wires) using conductible ink. In those lessons, the learners design and paint electronic systems, which can be integrated in an interactive book project.

a. Aims: familiarizing with the terms and related hardware; understanding the components as a networked system
b. terms to be introduced: Sensor, Actuator, connector, main board LilyPad, input, output and meaning/function in a circuit/interactive system).
c. methods: Relation to sensory perception/the human senses, and/or learners to represent the components physically
d. Develop photo-work sheets for identification of hardware components, including learning material including exercises

Module 2 Developing an electronic circuit

In module 2 of the LilyPad Arduino based Smart textile introduction series, learners learn to develop a circuit, cable it and make it run by themselves pupils learn 1. to develop a circuit, cable it and make it run by themselves, 2. how to cable the components using crocodile clips. Exercises based on work sheets to arrange the components and cables, so that an LED glows continuously, or an LED shines on and switches off come along with the module.

Module 3 Developing an interactive system -programming Arduino LilyPad

In this module, the learners learn to program Arduino LilyPad main board by using the icon based drag and drop programming environment amici. In the session pupils are introduced to Amici software through worksheets with exercises related to LED on /off, or for a particular time) in the context of an interactive system. The aim is to make transparent computational thinking and modeling behavior by developing a program and understand that, and algorithms control computers, can be controlled. It intends the pupils to understand the computer as a shapable, controllable medium.

Module 4 Programming Arduino LilyPad- Getting familiar with Amici

The main aims of this module is to make transparent computational thinking/modeling, and algorithms control computer, understand the computer as a shapable, controllable medium to the learners by doing, testing and debugging. In this module, the issue of testing and debugging is introduced to the pupils by making them develop, test and debug a program by themselves. The interrelation of such processes which belong together, are addressed. Aims are to develop a program, test and debug it. The issue of bugs and debugging is addressed (original etymological meaning of the bug, esp. for younger kids!). Exercises to arrange the components and cables, so that a LED glows, or so that a LED shines on and switches off.

Module 5 Developing a project with Arduino LilyPad and AMICI

In this module, the learners are encouraged to develop an idea for an interactive project, based on sensors and actuators they know from the previous lessons. By developing an idea for an interactive project, have the identify the tasks to fulfill and the realization by themselves. Co-construction of knowledge is supported and learned through the working and design processes. This learning activity deals with using logic and algorithms.

Module 6 Painting electronic circuits

This module deals with particular connectors. Painting electronic circuits can be used as a vehicle to technology education in early age groups. Conductible ink in a pen is used for electronic components in the context of drawing images. As Buechley has stressed 'electronics aren't just for experts and engineers. Kids and amateurs should be able to play, too'. Buechley designed paper-based electronics for 'sketching' and folding [17]. Teachers like to get and test learning materials which are ready to use in the classroom, but also designed flexible enough to be amended individually according to their own purposes, needs, target groups and ideas. In the following example, learning material is presented. Using conductible ink, the issue of 'algorithms' as an endless set of activities which, after its' realization lead to a solution, is introduced for primary school level. Therefore, the paper cards (see Figure 1) were developed. In figure one the cooking of a pan cake is used as an example for an algorithm:

Figure 1. Drawn algorithm in form of a game. Learner to put together the images in the right order.

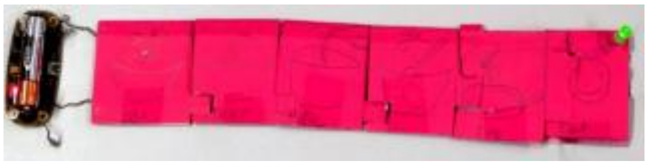

Figure 2. If every step is put together correctly, the LED glows.

For initiating the process, a blanco algorithm puzzle is handed out to the pupils.

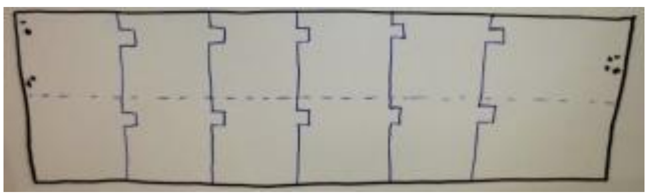

Figure 3. **A blanc paper algorithm puzzle is sketched for individual use**

In step 4, a connection between the ends has to be drawn.

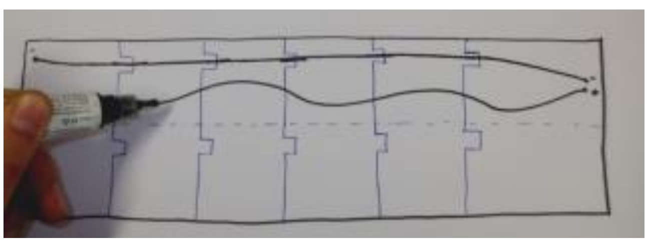

Figure 4. The connection is done using electronic ink.

Afterwards, it needs folding along the dotted line.

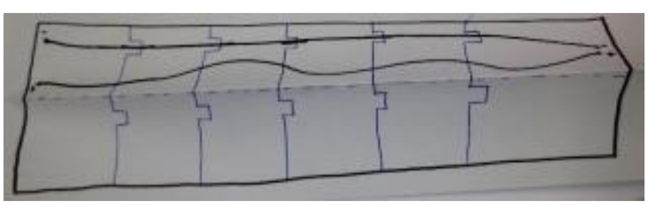

Figure 5. Fold along the dotted line.

In step 6 pieces are cut apart. Obviously there is only one correct order of the parts. Here you can see that there will be no electric connection.

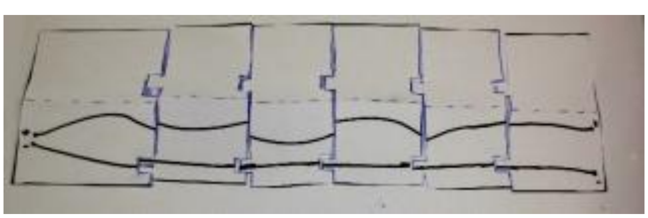

Figure 6. Cutting pieces apart.

In step 7 the parts are folded and numbered. At the front, an algorithm can also be written or drawn (e.g. a recipe).

Figure 7. Fold parts and number them.

In the 8th step, an actuator and a battery have to be wired to the end and to the starting point. Then the actuator will react if the algorithm is laid in the correct order.

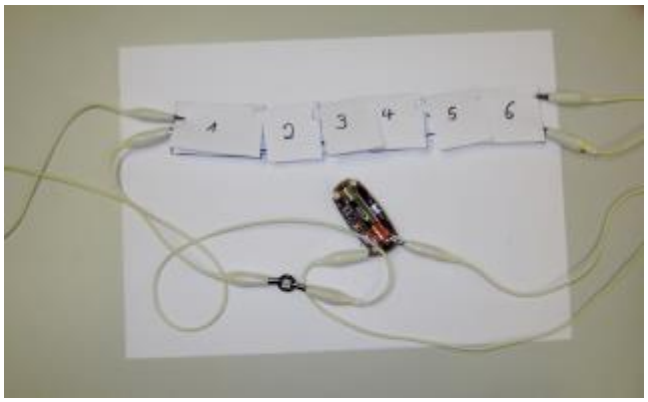

Figure 8. Cable an actuator and a battery.

3. CONCLUSION

As we have seen in the TACCLE 3 coding project [18], a variety of learning materials, media, activities and lesson plans were developed and are available online for testing in several languages and easy to use. They need to be used in practice. However, due to the project's target group of primary school teachers interested in teaching coding, a look at the initial teacher training is reasonable. As far as initial teacher training curriculum (not only in in Germany) is concerned, only few universities pushed the integration of computers beyond the tool paradigm into education study programs, including initial primary teacher training. Coding perceived as a key competence for pupils to get enabled to understand and control technology through design and prototyping processes, needs to be embedded into both the school curricula and teacher training at university level.

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