Sustainability principles through educational e-textile kit

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Abstract

Innovations in smart textiles technology are on the rise with a promise to add value to the consumer's life (Goodman et al., 2018). However, these innovations and the high development speed involved also raised concerns about environmental issues related to these trends (van der Velden, Kuusk, & Köhler, 2015). Therefore, TTorch project was created to bring different fields like electronics and textile engineering together to create a kit for educational purposes and follow circular economy principles during the process. TTorch is a creative toy with a development kit for up to 10-year-old children, using e-textile principles. The product kit creates a bridge between engineering and design, by letting the user explore a personal light source and build surroundings to it. The goal of the project is to show how interdisciplinary fields can work together and with that creating different opportunities. This paper gives a short overview of e-textiles, research on e-waste, textile waste and e-textile waste management. Further on it will focus on the necessary collaboration between design, engineering and industry by emphasising difference between core team and network around the core team. The collaboration aims to create an ecological product kit for educational purposes following the concept of STEAM. Discussions will include how collaboration between team members with diverse backgrounds, and their surrounding network was necessary to identify the specific gap in the market and to evolve the idea from product to development kit.

Keywords

e-textile, education, collaboration, design, sustainability

Different wearables and everyday electronics (like smartphones) push us towards connected living and have increased interest in smart textiles. The development of flexible electronic products has provided more ways for smart textiles to seamlessly integrate into everyday life (Goodman et al., 2018). Innovations have been so rapid that the focus of creating environmentally sustainable and, moreover, durable products, has been discarded. It is critical to start educating people on the topic early and to bring textiles closer to the science world. A study by Ercan and Bilen (2014) showed that primary school students are insufficiently taught about electronics waste awareness which plays an important part in smart textiles. Furthermore, the study states that the need for the environmental education of individuals and societies has emerged with the current increase in environmental problems. Especially in the e-waste field with great amounts of electronics shipped to third-world countries and then buried in landfills or burned. To achieve successful solutions, it is essential to have collaboration and to share knowledge between different fields of expertise. Thus, creating an interdisciplinary development kit for kids would create awareness for sustainability in several research areas, like textiles and electronics, early on.

The article will start with a short introduction to e-textiles, electronics and textile waste managementand research on e-textile waste management. The overview gives fundamental knowledge about current research on the topic and context for the necessity of environmental sustainability education. Further on, the TTorch project will be introduced with a focus on the topic of environmental sustainability with e-textiles. The article will discuss creating a successful collaboration when the team members have different cultural backgrounds and are working in different countries. Moreover, how the core team size is kept small and how additional value comes from network collaboration across the entire field.

E-textiles

E-textiles (electronic textiles) are part of a bigger field called smart textiles. Smart textiles are fabrics or apparel products that contain technologies which sense and react to the conditions of the environment they are exposed to, thus providing the wearer with increased functionality (Van Langenhove & Hertleer, 2004). The conditions or stimuli can be of mechanical, thermal, chemical, or of combination nature (Van Langenhove & Hertleer, 2004). E-textiles are smart textiles that have electronics incorporated in them by using different integration technologies, like crimping, laminating, soldering etc (Van Langenhove & Hertleer, 2004).

The global e-textiles (smart textiles) market is growing rapidly, rising from USD 795 Million in 2014 to a predicted $4.72 Billion by 2020 with a predicted growth of 33.58% between 2015 and 2020 (Goodman et al., 2018). There are many health and quality of life benefits of e-textiles in medical, healthcare, sports, and quality of life contexts, where they can, for example, facilitate health monitoring (Katashev et al., 2019). Moreover, Suunto Movesense Sports Bra with integrated textile electrodes for heart rate monitoring is available since early 2019 (Suunto). Additionally, Levi’s Commuter Jacket made in collaboration with Google helps bike commuters make a safer and more convenient trip (Levi's&Google). The jacket has already been on the market for many years. Energy harvesting is also entering the smart textile world since it is possible to use the movement of a human body as an energy source (Hou et al., 2013; Hu & Zheng, 2019).

Innovations in smart textiles technology promise to add value to the consumer's life and satisfy the textile industry's demand for new market opportunities. However, these innovations and the high development speed involved have a counterpart as well: they raise concerns about environmental issues related to these trends. There is a knowledge gap to support the decisions. To fill the lack of environmental knowledge of these designers, their managers and clients as well. Since textile designers make numerous product development choices and influence the architecture of products based on the market and user insights. (Van der Velden et al., 2015)

Environmental sustainability in e-textiles

However, since the smart textile field is interdisciplinary and requires knowledge transfer from the textile, ICT and electronics fields, it is even more important to focus on environmental friendlyness before products reach the mass-market. Since e-textiles contain both textiles and electronics, it is critical to have an overview of the state of waste management in both the electronics’ and textile industries.

E-waste and textile waste

Ilankoon et al. (2018) present in their work that the current status of electronics waste management estimates that about 44.7 million tonnes of e-waste was generated in 2016 and is expected to reach to 52.2 million tonnes in 2021 with an annual growth rate of 3-4%. Furthermore, they state that the EU formed the WEEE directive, Directive 2002/96/EC in February 2003, (EU, 2003) and it promoted reuse compared to recycling by also emphasizing that producers must take responsibility for the collection and treatment of their end-of-life equipment. It was reported that within the first few years since the implementation of the WEEE directive, about 67% of collected e-waste in Europe remained completely unaccounted for. Since the initial legislative framework did not achieve the desired goals, the European Commission revised the directive and the new WEEE Directive 2012/19/EU (EU, 2012) became effective in February 2014 (Ilankoon et al., 2018). According to the Directive, the Member States are expected to make sure that from July 1, 2006, newly marketed EEE shall not contain any lead, mercury, cadmium, hexavalent chromium, polybrominated biphenyls (PBB) or polybrominated diphenyl ethers (PBDE) in concentrations above the defined maximum concentration values (MCVs) for homogeneous materials (Wäger et al., 2012).

Meanwhile, in the EU alone, clothing and household textiles are the fourth most polluting products, from a lifecycle perspective (Beton et al., 2014). Globally, 3% of all greenhouse gas emissions are caused by the production and use of textiles (Nørup et al., 2018). In general, the consumption of textiles is rising, not only because of population growth but also because increased prosperity has led to countries such as China beginning to approach European and American levels in this regard (Beton et al., 2014). In Denmark and Sweden, the consumption of clothing and household textiles has increased, respectively, by 62% (2003–2008) and 40% (the period 2004–2014) (Nørup et al., 2018). Therefore, since the e-textile field combines two quite worrisome markets from an environmental point of view, the focus on getting people to think about creating environmentally sustainable e-textile products must be greater.

Both the electronics' and textile waste management fields are currently researching how to improve the situation. For example, Sahajwalla and Gaikwad (2018) write about an emergent alternate class of technology which can transform e-waste plastics into high-value products 'Microfactories'. Emerging Microfactory technologies are addressing the e-waste plastics problem by transforming them into value-added products such as Grenew briquettes for steel making, supercapacitors, silicon carbide, polymer composites and 3D printing filaments. Also, on the textile field, the Trash-2-Cash research project (Trash-2-Cash, 2015-2018) started with EU funding and with an the aim to create newly regenerated fibres from pre-consumer and post-consumer waste. The project included 18 partners spanning 10 countries including designers, design researchers, scientists, raw material suppliers and product manufacturers from across Europe. When the project ended in 2018 the outcomes were high-quality materials and product prototypes from waste, offering companies in various industries (fashion, interiors, automotive and other luxury goods) new eco-fibre options. However, the pace of change is still slow. E-textiles still haven't reached the mass-market and thus, all the mistakes with e-waste and excessive textile waste can still be avoided. Therefore, early education on e-waste and textile waste is critical.

TTorch product kit

TTorch is a kit for children to learn with e-textiles about materials and technology and through the animal character about the animal's capabilities and its living environment. TTorch first kit lets children imagine who lives in deep seas. The main part is a character, octopus Ceffys (Fig 1 and Fig 2). Toy character is mostly ready-made, however, it will be visible how it is built. Supplementary add-ons, like e-textile quilt blanket, with different storylines, will be available that could be put together by the children. This creates and gives the opportunity to explore the character and its functions and then develop the surroundings via blanket and story booklet. The booklet is being available as printed or in online form, to teach different facts about the character and its natural environment, including topics like pollution in the oceans. The kit brings together technology and the textile field from early on by focusing also on the environmental sustainability of e-textile products. The kits and products can be returned to the creators after their life-cycle by shipping them back for disassembly and reuse. This systems supports the closed loop idea where the product life is circular.

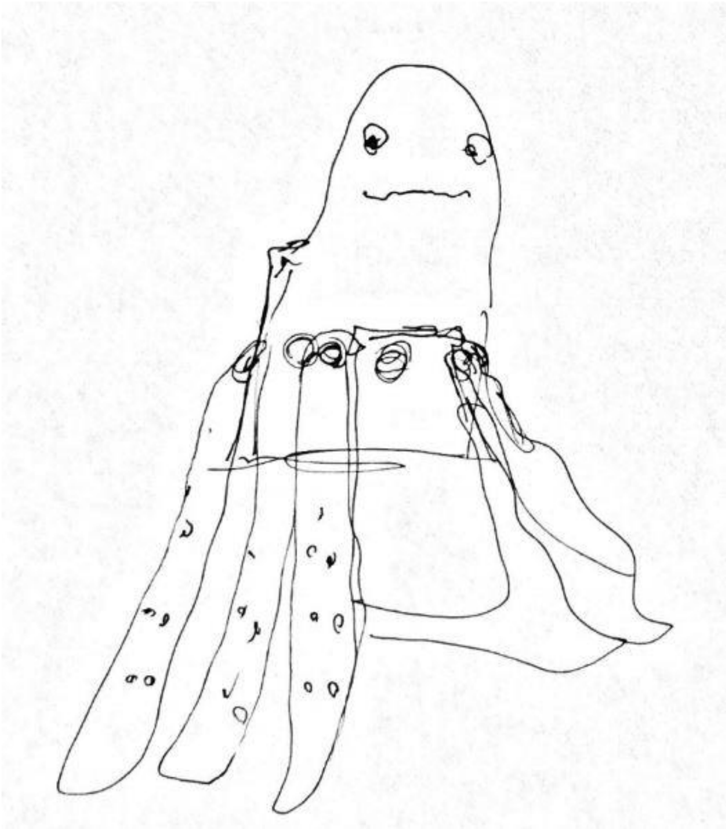

Fig 1. Early sketch of Ceffy the Octopus

Fig 2. First protoypes for TTorch

Context and use

The aim of the kit is to reach as many users as possible. Therefore, the kit can be experimented with in workshops and/or at home. Workshops at events, schools, kindergartens and even at birthday parties could provide an opportunity to see what is possible and how the kit works before buying it. Depending on the age of the children, assistance from adults may be necessary. The connections between nature and technology become clearer through this hands-on approach and textiles make it easier for children to get started with these topics. It allows the use in interdisciplinary teaching methods. For example, preschools could use the kit in textile focused courses, technology courses or nature and biology courses.

As the parts of the kits are interchangeable, they will be useful in group learning and collaboration at an early stage: by sharing and exchanging parts or by building one big creature together.

The availability of information and a personal introduction to textiles and tech are essential for the success of the kit. Since visual media is an effective communication method, it is also necessary to create tutorial and inspirational videos explaining the different ways in which the kit can be used, how the electronics work in the textile and why they are used.

STEAM and education

The kit contributes to the concept of STEAM (Science, Technology, Engineering, Arts and Maths), to motivate children to learn with a toy that they can even design themselves. Using nature as the central theme provides opportunities for education on multiple levels and subjects.Moreover, the flora motif creates a base that focuses on nature and sustainability.

Peppler (2013) mentioned in her paper that STEAM-powered tools and materials allow for open-ended exploration, a high degree of personal expression, and aesthetically compelling possibilities. Also, how emerging tools, materials, practices, and products at the intersection of the arts and the STEM disciplines could revolutionize computing education as well as have rippling impacts within each of these fields. She showcases that in their study, e-textiles bring together knitters, composers, dancers (as end users), biologists, and computer scientists. Thus e-textiles demonstrate how interdisciplinary the work can be.

Developing a STEAM educational product, interdisciplinary knowledge from all involved fields must to be gathered, as well as experts on pedagogy to assess the realistic usage and possible handling of the kit by children, foucsing on their motoric skills for example.

The team’s backgrounds merge knowledge from all STEAM fields. Thus, it is possible to make an educational kit with artistic methods and designs together with basic engineering and electronics principles. Bringing in experience from smart textiles research, environmental sustainability principles can then be incorporated into the kit’s design. There are more examples of STEAM use in environmental sustainability education.

For example, in 2016 Nord Anglia Education announced the details of its new science, technology, engineering, arts and mathematics (STEAM) curriculum, developed in collaboration with one of the world’s most influential universities, the Massachusetts Institute of Technology (MIT). Students were challenged to solve a real-life problem facing their local community, e.g. they had to identify and describe an environmental problem in their city and it’s impact on the overall health of the city including air, food, water, energy, transportation and waste. The initial programme was launched in 13 schools in September 2016, and the project is still ongoing (Education, 2016).

Parts

Each kit consists of several parts which are prefabricated, so that the assembly of the product would be more enjoyable. Prefabrication also includes thermoplastic polyurethane (TPU), so that there would be less sewing required, resulting in more durable products in the end. Usage of TPU films enables the electronics to live longer in textiles, especially when it is necessary to wash them and (in general) make them more resistant to the influences of moisture or dirt. Later, electronics can be delaminated and the parts resused.

Moreover, different conductive materials and/or electrical conductors, like stainless steel snap buttons, are used for creating mechanical connections in the circuit. For example, the use of colour code snaps or conductive hook and loop strips for making the connections within circuits.

The components do not include printed circuit boards (PCB), in order for the product to be simpler and environmentally sustainable. Furthermore, by leaving out PCBs and designing only mechanical circuits, it creates more options to play around with the kit.

The goal of the TTorch is to be simple enough and easy to understand, that children could assemble it by themselves. Additionally, they would be able to focus on the playful part of it, rather than spending effort on simple connections and getting started.

Make of the kit

One of the main goals was to create the kit in an environmentally sustainable way. Textile parts of the kit are made of fabric leftovers from a network of textile product manufacturers. Using leftovers also creates awareness of the materials and their origin. Since fabric scraps can include very different materials they allows for more creative freedom and assembly options. A digital print on some of the parts might be used to brand the parts, and to give the possibly different materials from the leftovers a more uniform look.

It is complicated to use electronics sustainably with the current state of the technology. Currently, one of the best options is to work towards a more sustainable design of everyday objects. An efficient design allows for reduced waste production by creating patterns with a low percentage of fabric loss. The layering system of the product by TPUs make parts reusable and/or recyclable by disassembling the layers under heat. The designing phase focuses on creating a valuable product that can be repaired instead of being utilized.

Moreover, the sourcing and production of TTorch will be planned regionally, which reduces emissions for transport and logistics. Establishing a local circle of product creation, provides an opportunity for closed loop production. Meaning, when products are not used anymore or need repair then users can return them. Closed loop provides the possiblity of control over old products and makes a second hand market available.

Collaboration

TTorch Team collaboration

TTorch interdisciplinary two member core team consists of experts in the fields of textile and product design and electronics know-how together with textile and garment production experience. The core team first member has industrial and textile design background with e-textile knowledge and creates different prototypes and product concepts in the field. Second member has expertise in textile and clothing engineering with experience in different production companies. The two perspectives create results from discussions, as problems can be evaluated from various sides. Questions, that can not be answered by the team members, can be identified and external experts from surrounding network can be consulted.

It was essential to see how the skills are best divided between tasks. It was identified how to use the previous experiences of partners, like having an overview of realistic production processes while also bringing the newest information from the research field. Moreover, the collaboration complemented the project by transforming the idea from just a toy product to development kit that would educate on critical topics.

Since the team members are located in different countries, regular discussions are mostly held through online media, whereas a few physical meetings, to work together and form team thinking, are also held. The project contains both practical and theoretical tasks. All planning, outline discussions, and sharing of ideas could easily be done through email and files shared online.

In the first prototyping meeting it became clear how important it is to work together and be able to find solutions for the next steps and shape team integrity. Also, on the technical side, it was productive to work out small but crucial details to understand each others' perspectives and ways of working.

It was critical to meet and make the first prototypes together. While making and producing items together, it was easy to exchange thoughts on subsequent steps and explore the unique perspectives of different professional backgrounds. The different viewpoints created different designs, circuits and bonding technologies. For example, coding the female snaps to only plus side and male snaps to only minus side was avoided in the first prototyping phase. The engineering section could make the decision by creating the circuit ahead on paper and demnostrating that it would not correspond on the toy and on the blanket the same way. Discussions about proceedings and solutions gathered argumentations from both design and technical side, which lead to fast pace in decision making by the team speeding up efficiency in the process.

Collaboration with external network

Authors have a network of experts from related fields. It was important to keep the core team small but include knowledge and experience from other fields. For example, including mentorship from business and marketing experts with several years of experience, also in research centers, adds vital expertise. Moreover, the build-up of electronic parts needs additional consulting, thus, low voltage systems and microelectronics experts were involved in source good electronics materials and ensuring technical accuracy from the beginning. A small core team was able to make decisions rapidly and move forward while receiving support from an external network, like project managing, illustration and story build-up for the toy etc. Thus the first prototyping was already done one month after the project started and first feedback from children was received within the first 45 days.

Building up the educational aspect and logic of the kit experts on pedagogic research fields (like preschool education) are invited for discussion and feedback. Moreover, a group of parents gave feedback via questionnaire since they are also in the main end-user group. The feedback and questionnaire mainly accentuated the attractiveness of the tech product with a tactile appearance and wireless communication. Easy packing for different locations (like kindergarten and vacations) was equally crucial.

The background and knowledge from manufacturing makes collaborating with industry partners easier and provides opportunities for direct discussion with technical partners. Having this expertise in the core team makes it is possible to engineer realistic sustainable processes from the beginning. The different backgrounds from team members support having various industry partners both for supplying materials (like fabric leftovers or electronics) and setting up production later on in the project.

Communication with the target group and collaborative network

A big part of the project is the interaction and the electronics. The user group 1 includes children between the ages of 3-7. During the process, regular small tests were done with children, to get feedback for mainly two reasons: are the interaction and ideas interesting enough for children and are their motorical skills and awareness enough to understand every aspect of the toy. For example, Fig 3 and Fig 4 represent a test during prototyping phase. During and after the test it could be concluded that kids needed constant stimuli where the blanket could help.

User group 2 are the parents and other adults who are interested in the toy for their children. They are also involved in the development process to get feedback about the toy and to join the usability test with confidence, as the parents' moods have an impact on the childrens' moods (Häusser 2012). It is vital to explain the prototypes understandable way and on eye-level as e-textiles are not well known and it might be challenging for the parents to estimate the potential risks through electronics in the toy.

Fig 3. Small test between prototyping with children to see the first reactions.

Fig 4. Small test between prototyping with children outdoors.

Challenges of collaboration

Pohl (2005) et al. study shows that researchers perceive transdisciplinarity not as an essential part of problem-driven research but just one additional demand on the part of programme management. It would be more significant to shift knowledge of specific disciplines in such a way that it is most useful and meaningful. Thus, creating the right philosophy and momentum within the team was necessary. For example, clarifying the contract, tasks and money distribution openly was a primary task.

Collaboration is done over distance, therefore, making and sharing schedules as early as possible was crucial. If problems (like insufficient time for completing a task) did occur, the other partner could take over, provide support or do both. Extra attention was needed and put into using a correct and personal communication language. The backgrounds, cultural contrast and the fact that first languages differ may affect how topics and ideas are perceived. Thus, sharing ideas over video or e-mail was critically checked to be clear enough and on schedule.

Discussions and conclusion

The innovations in the e-textile field have been so rapid that the focus from environmental sustainability of the processes and products has been discarded. Although e-waste and textile waste management are investigated, the process is slow. It is essential to remind and teach environmental sustainability as early as possible. Thus, creating an interdisciplinary toy and development kit for kids with sustainable materials and techniques would create more awareness in different environments and networks.

One of the aims was also to show how collaboration creates and innovates. STEAM as a concept allows playful education on several layers at once without being too complex but suiting children's different perspectives and interests. The TTorch toy octopus is mostly ready-made, however, it will be clear how it is built. Supplementary add-ons (like an e-textile quilt blanket with different storylines) will be available that can be tested and put together by children. Providing the opportunity to explore the character and its electronic functions via a blanket and story booklet brings interdisciplinary fields closer together at an early age. Creating solutions, that can be experienced, are essential to creating memorable knowledge and validating ideas with further guidance to developments (Bas van Abel et al., 2012).

In the TTorch project, the knowledge and perspectives of different disciplines, like engineering and design, were combined and harmonised to discuss the materials, production technologies and sustainability of the product. Involving external partners only when necessary made partners more willing to give conciseinput without being fully involved in the project. It has been demonstrated how the network is collaborative and supporting partners are contacted only when necessary. Supporting the project as as equal partners were parents, educators and the children themselves, so that the interaction and ideas behind prototypes would be adequate for children and according to their motor skills.

Collaboration has its logistic and social challenges, however, the collaboration made the project creation process versatile by elaborating the initial idea from one toy to a development kit with several parts, a story and a specific market gap. The potential of the project increased significantly which could be measured monetarily by having add-ons on the kits but also reaching and educating more children with different storylines.

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Barbro Scholz

Barbro Scholz is an artist and textile designer. She has a background in design with a focus on electronic textiles and interaction, her interest is in the impact of designed objects especially textiles with their poetic tactile character. With that, Barbro shares her knowledge by teaching students in (e-)textile design. Additionally, she is one of the founders of Stühmer|Scholz Designbüro based in

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