Staging Constructionist Learning about Energy for Children with Electrochromic Displays and Low-Cost Materials

Löchtefeld, Markus; Milthers, Anna Dagmar Bille; Merritt, Timothy

Published in:
MUM 2021: 20th International Conference on Mobile and Ubiquitous Multimedia

DOI (link to publication from Publisher):
10.1145/3490632.3490654

Publication date:
2021

Document Version
Accepted author manuscript, peer reviewed version

Staging Constructionist Learning about Energy for Children with Electrochromic Displays and Low-Cost Materials

MARKUS LÖCHTEFELD, Aalborg University, Denmark
ANNA DAGMAR BILLE MILTHERS, Aalborg University, Denmark
TIMOTHY MERRITT, Aalborg University, Denmark

Fig. 1. Wind energy activity - (From Left) 1) Participant assembling the turbine and choosing colours for the fan blades. 2) Blowing on the assembled turbine to cause it to spin and generate the power to change the image on the display. 3) Watching the effects of speed and direction rotation on the DecoChrom display. 4) Playing with the turbine and reflecting on how it works.

Well-funded classrooms often provide a variety of learning materials such as computers, robotics and other expensive equipment to facilitate STEM Learning activities for children. However, exploring natural phenomena such as electrical energy is possible through very simple activities. In this paper we explore how cheap low-cost materials and simple electrochromic displays can be designed to support experiential learning about energy and power generation. For this we employed a mix of open-ended play and exploration as well as staged and goal-oriented activities. We developed two learning activities that involve children constructing working models that generate power including constructing a wind turbine and assembling a solar power harvesting house. We studied how children engaged in the activities and how the materials helped them understand the topic. All children could construct and complete the building tasks and were generally positive about the experience. We identified challenges encountered by children including interactions with the construction materials and electrochromic screens as well as insights about the mental models children have. We discuss challenges for staging learning through play with found low cost and local materials and provide implications for the design of constructionist oriented STEM learning.

CCS Concepts: • **Social and professional topics → K-12 education**; • **Applied computing → Interactive learning environments**.

Additional Key Words and Phrases: STEM, constructionism, Experiential learning, Maker Movement, FabLearn, Electrochromic Displays

Manuscript submitted to ACM

ACM Reference Format:
Markus Löchtefeld, Anna Dagmar Bille Milthers, and Timothy Merritt. 2021. Staging Constructionist Learning about Energy for Children with Electrochromic Displays and Low-Cost Materials. In *20th International Conference on Mobile and Ubiquitous Multimedia (MUM 2021), December 5-8, 2021, Leuven, Belgium.* ACM, New York, NY, USA, 17 pages. https://doi.org/10.1145/3490632.3490654

1 INTRODUCTION

In recent years we have seen an increase in interdisciplinary Science, technology, engineering, and mathematics (STEM) approaches utilizing the Maker movement and mindset e.g. in the FabLearn initiatives [5] that combine fabrication and computational thinking [8, 9, 11]. An ambitious vision for making, students can engage with equipment and specific methods to experience phenomena first-hand. While this experiential approach can help in teaching fundamental concepts e.g. cause and effect, etc. Open building and assembly activities might stimulate creative curiosity [35]. At an early age, activities can involve step-by-step lessons initially, yet the aim is often to equip the child to be more self-directed in their learning. Activities can encourage the child to adopt a mindset in which they build, experiment, iterate, and reflect as they seek to acquire the needed skills to develop a solution [36]. This follows Papert's constructionist approach [29] and the focus on cumulative knowledge integration.

While this area has proven to be widely successful, learning opportunities and diversity of corresponding learning materials for children vary dramatically across the world, largely dependent on financial resources available. It might be common for a child in developed nations to not only have multiple computing devices but also physical construction toys, robotics and other educational materials that follow this principle, available at home and in the classroom. However, this is not the case in most parts of the world [37]. Especially in developing nations, where resources are more limited, there is a struggle to offer similar learning opportunities, and unfortunately, children are less exposed to digital technologies. While, for example, in computer science educations, analog learning materials have been adapted to stage similar experiences [4], less work has focused on creating low-cost constructionist-oriented learning materials for STEM education.

To acquire 21st-century skills of solving complex problems, it is absolutely essential to extend learning over the confines of the textbook and lecture-based learning and to encourage applying the knowledge in creative contexts [12]. We appreciate the approach of adapting materials and involving the child in constructive play and learning, however, it requires a lot of work beforehand and teachers need to spend a lot of time preparing lessons and curating materials to make available to their students. Working with our collaborator, we are motivated to explore, how rich learning experiences can be staged to offer children high quality learning, without the need for expensive digital technologies. The goal of this paper is to work towards a toolkit for developing countries that is comprised of low-cost materials, that ideally can be integrated and extended with more locally sourced materials and that allows to stage STEM learning activities easily.

The rest of the paper is organized as follows: First, we review related research in constructionist learning and fabrication for children, as well as inexpensive emerging technologies that might facilitate STEM curricula. Next, we describe a set of learning activities that we developed, based on electrochromic (EC) displays, and simple physical construction materials which are aimed at teaching children about energy and power generation. Then we describe play studies conducted over four days with 29 children to understand how children engage in the construction tasks. We were interested in how the children engaged with the simple two-state displays and how the technology might be integrated into STEM learning activities. We summarize the challenges and opportunities as well as observed patterns of play. We discuss the findings in relation to constructionist learning and personal fabrication and provide implications for the design of EC displays for staging lessons and insights about developing simple, low-cost learning materials for STEM learning for children. We conclude by mapping out the important future work needed to make rich constructionist play experiences available more widely for children from all socio-economic backgrounds.

2 RELATED WORK

We live in a time with higher population, interconnection and more technological advancement than ever before in human history. At the same time we are facing large-scale complex problems that will require interdisciplinary problem solving skills. Especially in STEM subjects, the idea of incorporating novel educational methods has been heavily explored through, for example, tinkering, play or maker-based activities [24, 35, 36]. Chu et al. used maker activities to construct artifacts which afterwards would be used in a scientific experiment, for example building an electric sifter to separate salt and water [8]. These approaches are often grounded in constructionist learning theory [29], presuming that children are particularly engaged and effective learners when they are building artifacts. In this paper we closely follow this idea, combining building activities with teaching about energy generation.

Several prior works also argued that it is decisive to give space to creativity and artistic expression and incorporate it into the curricula. Such approaches are also referred to as STEAM (STEM + the Arts). It incorporates practices from art and design into science, technology, engineering and math education mostly for K-12 or even to up to K-20 education [6]. The aim is to tackle STEM problems through creative thinking or design thinking [25]. However also the other way around - demonstrating how artists and designers can exploit STEM areas - is a viable option to motivate students to extend their STEM knowledge. STEAM principles have been implemented in many computer clubhouses, which focus on the creation of art and design through technology use [34]. Furthermore, many platforms such as Scratch [34], LilyPad Arduino [31] or EduWear [20], to name just a few, embraced it as well. More recently, STEAM research has explored theatrical performance [19] or screen printing and interactive materials [22], as platforms for science and tech learning. Another practice that has been explored in the past is the construction of paper circuits [27, 30], to challenge practices around electronics design and open it up to a larger community. Similarly, in this paper we aim to replace more expensive materials with more accessible and approachable materials and combine them with electronics to open up learning possibilities to new communities.

Malone [26] found that fantasies (evoking images of objects or situations not present) represent a key ingredient of fun learning which was also sustained in [9] with the Maker Theater. Both of the proposed curricula contain potential for creative adaptation and extension which makes them very likely to not only be educational but also entertaining and fun. Furthermore they are also based on visual media which makes it easy to assess and share the accomplishment which has also been highlighted by Weibert et al. [38] as a key element to a successful learning process. With the activities presented in the present paper, we closely followed these suggestions and offered customisation possibilities allowing the children to design their own elements that can be added as well as the ability to incorporate the resulting artefacts in narratives. For example, the children would construct the house in the solar power exercise, which could easily serve for narrative expression.

However, the current directions of maker education research have also been criticized due to potential dangers of the current style of what maker education means and how it can restrict equity for marginalized groups [37]. And compared to how much research has explored these kinds of maker based or constructionism led activities in developed countries, the amount of work focused on developing countries is extremely limited. There are some investigations into how to transfer approaches, for example the concept of a computer club from Germany to a refugee camp in Palastine [1], but only few examples of work focus on maker activities. Alekh et al. explored maker based activities in semi-urban India [3]. Their water rocket building activities demonstrated that such maker activities can reduce tension and pressure among the students due to their collaborative nature. Weibert et al. investigated how upcycling activities can lead to a maker mindset [39] and while the comparison of their activities in Germany and Palestine showed very different approaches to the topic it yielded comparable learning outcomes. While the activities presented here are not carried out in such a setting, they are developed with developing countries and refugee camps in mind, focusing on low-cost and easy extension. Obviously these activities will still require cultural adaption and contextualization to the final settings.

3 DESIGN OF LEARNING ACTIVITIES

The goal of these learning activities is to enable large populations of children to learn about sustainable possibilities of energy production without requiring well-funded classrooms, in learning through play activities. The initial inspiration for the here presented learning activities comes from the LEGO® Education set Renewable Energy Add-On set[1]. This add-on set - which is based on the LEGO® Mindstorms® kits - is designed for educators to teach about renewable energy sources, specifically the functionality of solar cells, wind turbines and hydro-electric power plants. For this kit, a clear lesson plan with planned experiments and designs already exists and has been successfully used in schools in the past [2]. However, the set also comes at a relatively high price (more than 140 Euro just for the add-on set as of the time of writing this paper), which makes it inaccessible for many classrooms around the globe. The price point stems from the materials used, expensive electronic components and extremely durable and reconfigurable LEGO bricks made from ABS plastic. To overcome these problems and open similar learning experiences to a larger audience we present here the design of a physical construction set that was developed to be low-cost, yet with comparable possibilities.

One of the main aspects of the LEGO Education set are the building activities it is tailored around. Keeping these activities as part of the overall learning design was crucial for our design. Given the high price point of plastic bricks and also the connected size and cost of shipping these, we decided against using such bricks. For then main material we explored a lot of different materials, ranging from plastic sheets to fabrics. However, we ultimately settled for thick paper (cardboard of 0.5mm thickness) as the main material used in the building activities. The main reason for this is its availability, but also the idea of being able to re-purpose (recycle) packaging materials and other locally existing materials and integrate them into the construction activity. While paper provides a good base and has been used for constructing objects for centuries e.g. in Origami and Kirigami, often extra materials such as glue or adhesive tape are used to connect the different elements. However, such materials bring a certain feeling of finality of the assembly, and make it harder to motivate re-use and changes to the assembled artefact. Therefore, we decided to make use of reusable round head paper fasteners. These can be used to connect multiple pieces of paper using holes that were created by a hole punch, Which is also a common method to create articulated paper sculptures. We hope that by providing elements that can be reconfigured and easily re-built, the system woud stimulate curiosity and exploration. Furthermore, the use of a hole punch can motivate the inclusion of other elements and materials and even re-appropriate local materials to further reduce potential costs. For our particular implementation we used plastic clips that are functionally similar to commercially available metal round head fasteners, however lighter and safer to use for children.

The second substantial problem with the LEGO Education kits are the comparably complex electronic components used. Besides using a complex display technology including a display driver, they also require a battery. This not only seems counter-intuitive for an educational set focusing on energy generation but also introduces some extra prohibitive

[1]https://education.lego.com/en-us/support/machines-and-mechanisms/renewable-energy-set

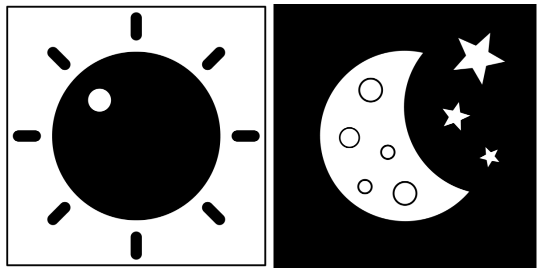

Fig. 2. Graphic design of the EC display - (Left) Sun state of the EC display. (Right) Moon and stars state of the EC display.

elements for large-scale adoption. For our activities we propose the usage of electrochromic displays as a low-cost and low-energy alternative. In recent years it has become possible to fabricate transparent and non-uniform displays using electrochromic ink [14, 23, 28] and they have been used for a variety of different applications ranging from simple paper augmentation in board games [18] to more complex wearables [13, 15]. Even applications focussing on children have been explored, e.g., using the displays to cast interacitve shadows for storytelling [16, 17]. This display technology allows creating dynamically animated graphic elements based on 'electrochromism', which is the ability of some materials to change their optical properties through chemical oxidation or reduction when an electric current is applied to them. Usually the change is from a color, e.g. blue to a transparent state and occurs at relatively low voltages 1.5-3V.

We follow the process described in [14] and used the Ynvisible Ink-Kit[2] to produce the displays. One of the limitations of this approach is that the electrochromic (EC) displays can only switch between two different graphics, however to switch between them only the direction of the current flow has to be switched. This enables, for example, to turn a connected DC Motor in one direction to show one image, and by turning it the other way the second image would show up. While these displays do not provide detailed information about the voltage and current production (compared to the LEGO Education kit) the switching speed is affected by the amount of voltage and current supplied. This means that the children will be able to infer the amount energy produced by the time it takes to switch between the different images. These displays can be directly connected to an energy source, which makes it fairly adaptable and can also be used outside the learning activity e.g. for narrative play. This idea was also considered for the graphic design where instead of a clearly energy related graphic, we decided for a design that is more generally applicable and could also be included in different activities. We decided to use a Sun in one of the states and a Moon and Stars for the other state. This can be seen in Figure 2.

The energy learning activities were designed to provide an experiential learning opportunity so that children would have the ability to generate power directly through their actions [21]. We designed two activities, that both include a fabrication part in which a prototype had to be constructed and the experimentation part, in which the children's actions would allow them to learn about the energy production. The first part is related to wind energy and the other one deals with the topic of solar energy.

3.0.1 Wind Turbine Task. The first activity is based around wind energy, and modeled after a wind- or hydro turbine. For this we utilize a 9V DC motor on which we mounted a round plate to which then a set of up to 8 blades can be connected using two round head fasteners per blade. This can be seen in Figure 3 (left). The blade elements were

[2] https://www.ynvisible.com/ec-kit

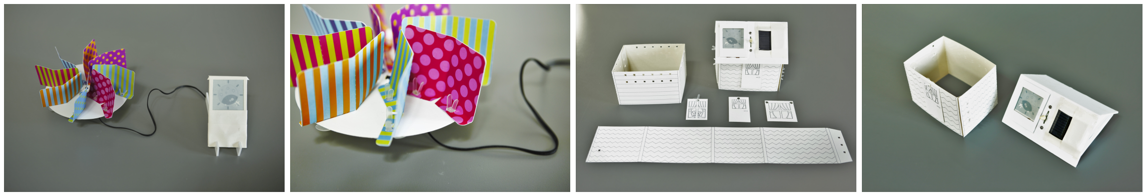

Fig. 3. (left) Wind power components including wind turbine and EC display. (middle-left) Detailed view of assembled wind turbine. (middle-right) Solar power activity components including wall parts, windows, doors, solar panels and EC display. (right) Detailed view of house and roof with solar panel and EC display.

designed with a bend at the foot and a small v-shaped gap. This made it easy for the children to bend the elements to be able to assemble them. Also the bend increased the speed when blowing onto them, which is crucial to create enough energy for the display to switch, while at the same time allowing for clear distinctions of produced energy between lower and faster wind speeds. The design was reached through an iterative process in which we evaluated the sturdiness and needed effort to drive the displays. The final paper elements were cut using a Zünd digital cutter out of 160gsm paper, however, they could also be cut out by hand. The children, would assemble the paper parts and then connect it to the motor. Here we also give the possibility to change the number of blades attached to it, which will require more or less effort when blowing onto them to change the EC display. Also changing the angle when blowing onto the wind turbine had a significant effect on the changing speed of the display.

3.0.2 Solar Power Task. For the solar task we opted for a more complex building tasked compared to the LEGO Education set, where it is simply a solar cell on a rotating element connected to a measurement unit. To stimulate re-use as well as personal exploration and expression, we decided for the more complex construction of a house. All parts for the prototype were cut from 160gsm paper using a Zünd digital cutter. The roof consists of two triangles and three squares connected with finger joints. On one of the roof sides we installed a simple 3V solar cell connected to a 3-way switch, which was then connected to the EC display. The different elements were connected with simple pin headers and pre-made cables that were orientation invariant so they could be easily assembled. The 3-way switch is used to switch polarity, and in the middle position switch-off the power transfer to the EC display. For the later described study, the rooftop was already fully assembled to fit the time restrictions. The lower part of the house that supported the roof is constructed from one-large element that had an equidistant pattern of holes for the round hole fasteners. On the one side, this allows to construct the stable square base, but on the other it allows children to attach decorations, such as doors and windows (compare Figure 3 right). While a set of simple designs was provided, here again more elements can be created if so desired. For the below described evaluation, we utilized a standard desk lamp as the light energy source as the study was conducted indoors, however, it would work equally well in natural daylight. Additionally, we provided cardboard elements in a cloud shape that the children could hold between the lamp and the solar cell to explore how this obstruction changes the energy production and changing speeds of the EC display transitions.

Overall both activities, are simple to create but can be easily extended and personalized to the children's wishes. Both sets are compatible with the lesson plans of the LEGO Education set, but at the same time allow for extension. Given that the lesson plans for the LEGO Education sets have been evaluated by researchers as well as practitioners, we are in the following less interested in the learning outcomes, but rather in the general understanding and ability to construct these sets by children in the target age group of 7-10 years. The overall hardware costs, including all the paper, the two displays, the motor and the switch was below the equivalent of less than 10 Euro. The source files of the design of the learning activities are available here: (Will be made available upon acceptance).

4 EVALUATION

In order to study how children respond to the learning activities, we recruited 29 participants, over 4 days, at LEGO® World 2020 which happened shortly before the COVID-19 pandemic. As the exercises are based on the LEGO® Renewable Energy Kit - which already have well established lesson plans with clear learning outcomes - we decided to mainly focus on the overall experience instead of the learning aspect. We were interested to understand how the fabrication element would support the children's motivation. How effective would the artefacts be in informing the children about the general area of sustainable energy generation? And lastly, how do children make sense of the experience, and what improvements would they suggest?

4.1 Participants

While the overall learning experience was, as already discussed before, designed with children between 7 and 9 in mind, we decided however, to extend the overall recruitment a bit to explore the potential in different age ranges. We recruited 29 children between 6-11 years of age with an average age of 8.46 years (SD = 1,34), including 6 females and 23 males.

4.2 Procedure

After the parents signed the consent form, filled out the demographics and gave permission for photographic and video documentation during the study, the two study facilitators would pick up the parents and the child and bring them to the study area. As the study area was not in the main area of the expo, this required a short 4-5 min walk. This walk gave the facilitators the chance to get acquainted with the child, through light conversation about the child's experience at the expo, but also to slowly prepare the child for the evaluation.

During the whole study, one of the two facilitators would take notes and transcribe the child's comments while the other facilitator would guide the child through the exercises. During this, the facilitators would ask the child about her experiences and help e.g. with the construction of the different artefacts. The questions where asked during the tasks as a contextual interview. They focused on the child experience, including positive and negative aspects, their understanding of the exercises and the connected learning goals and ways in which we could improve the artefacts.

For the evaluation, the two exercises where spread out over two tables. On the first table the child would start with the Wind Turbine exercise, and would begin with exploring the function of a fully constructed turbine. For this, the child could either turn or blow on the turbine and observe the change of the EC display.

Afterwards, the child was asked whether she has seen something like this and whether she understands how it works. This was then followed up by offering the child to build her own wind turbine which then could be tested again. On the second table, the solar power exercise was prepared. As described above, the roof was already fully assembled (due to time restrictions), however, we gave the child the task to first assemble and decorate the main body of the building. Afterwards, she would attach the roof component and explore the influence of the desk lamp light on the EC display. Lastly, it would also test the influence of the cloud shaped cardboard on the speed of change. After this, the facilitator would walk the child back to the registration desk and pick up the next participant. All in all, this took between 35 and 40 minutes.

Fig. 4. (From Left) 1) Participant assembling the walls of the house. 2) Decorating the house with windows and doors. 3) Roof with solar panels placed on walls and child observing the changes of DecoChrom display due to the light energy from the lamp. 4) Investigating what happens (or doesn't) when the light source is covered by a cloud.

4.2.1 Data Collection. As described above, one of the facilitators would keep constant notes on their objective observations of the children's progress. After each task, we would also collect the self-reported qualitative data of the child as transcribed by the second facilitator in the contextual interviews. The main facilitator was guiding the children along using the following main questions for each task:

- "Have you seen something similar to this in the real world before?" - we wanted to see whether the child makes the transfer to the real world.
- "How do you think this works?" - to assess the child's understanding and reflection on the task and indirectly assess their learning.
- "What was interesting about this task?"
- "What was fun about this task?"
- "Tell us about any problems you had." - these could include different levels of problems.
- "What could be done better?"

However, these questions only served as a general guide, the facilitators where free to add follow up questions or if a child was particularly shy or not interested, they could move on to another questions that seemed more suited to the moment. The answers of the children where noted by the second facilitator, so that the first facilitator could fully engage with the child. Besides the contextual interview, we also collected quantitative data. For each task we also collected Read's and McFarlane's Smileyometer and the Again-Again table [32, 33]. The Smileyometer is a a 1-5 Likert-type scale, and uses pictorial representations from which the children can pick one of five smileys ranging from 'Awful' to 'Brilliant' to describe their opinion of the experience. The Again-Again table allows us to measure the desire to engage in an activity again if it was found to enjoyable. The facilitator documented this in a table, which lists the activities on the left hand side, and has three columns with the possible responses of Yes, Maybe, and No. The child would be asked the question: 'Would you like to do this again?' When the child answered, the facilitator would note their response in the table.

5 RESULTS

We analyzed the results of the user study by considering the interviews as the primary source of analysis, and the questionnaire responses were used to validate findings resulting from the analysis of the interviews. The transcriptions from the study facilitators were first translated, and then analyzed and coded using a two-step constructivist grounded theory approach [10]. In the initial coding conducted by the three authors, we identified 14 themes that were sorted, compared and filtered to 6 salient themes which will be described in the next section. Additionally, the images and video clips of the participants' progression, were used to analyze the potential problems and shortcomings of the exercises.

5.1 Construction of Artefacts

The first thing the participant is asked to do, is to assemble the artefacts which facilitate the exercises: the wind turbine and the house for the solar panel. This was a substantial part of the experience as it has the potential for engaging the participants' commitment and creativity. In this process, observations have been made with regards to engagement, creativity, materials and difficulty. The small assembly task served its purpose of engaging the children and motivating them in the activity to support the learning experience. All except two participants used positive expressions such as *"It's fun to build it, and see what it does"* (P6) or *"It is cooler when you build it yourself"* (P4) which also highlights the importance of agency here. Only one participant described it as *"boring"* (P7), while another participant found it less interesting *"It's a little fun, but LEGO is better, because the wind turbine can't do more than one thing."* (P17) (We will return to the effect of the context of LEGO World later in this chapter.)

During assembly there was opportunity for the participant to make creative choices with colours and patterns, which the facilitators' notes indicate could create or increase engagement. For example, P24 built it after a color pattern or P15 who specifically mentioned that the choice of decorations for the house was fun and also was extremely engaged in the building of that artefact.

While the current material choices are not finalized and we hope in the future to adopt more local materials, several participants took notice of the materials explicitly and expressed a range of opinions. There were many who enjoyed the simple materials especially given the setting of LEGO World *"It was actually fun that it was paper"* (P29), while others disliked it: *"Not interested in paper. Only LEGO"* - (P7). The dislike was primarily linked with a comparison to LEGO bricks. Especially P7 showed a clear rejection and expressed that he owned LEGO sets that could do similar options at home.

5.2 Manual Task Difficulty

Some participants seemed to struggle more with the manual complexity of the tasks, and we find that this could be related to a lower age group, as the average age of the participants who had difficulties was significantly lower than the average age. Several participants had issues with the plastic clips. While it was less the working principle, the challenges seemed more related to the stiffness of the plastic clips, which were less flexible when used for the first time. The average age of all participants was 8.5 years old and the average age of children that found the manual tasks challenging was 7.7 years old. However, the majority of the participants did not exhibit any issues, but this of course needs to be taken into account for future work.

Another difficulty observed was in getting the wind turbine to spin quickly. It was intended to be activated by being blown on by the participants, but for three participants the resistance of the motor was too strong for the child to move the turbine rapidly with their own breath, and they would need the additional breath power of the facilitator.

5.3 Display Shortcomings

During the trials some issues with the artefacts became apparent. These issues were with the screens' shifting speed, the icons they displayed, and with the motor of the turbine being too strong to turn for some participants. When the artefacts had been assembled and activated, the electricity generated was used to shift the displays gradually between two images, a sun and a half-moon and stars. However, there were some participants who found the change in the

Fig. 5. (Left) Facilitator helping the participant assemble the turbine. (Right) Facilitator blowing on the turbine, while participant watches the display change.

displays too slow or not clear enough *"The change is too small"* (P19). And the facilitators observed for P17 that the change was too minimal and the participant thought nothing had happened.

Data also suggest that using sun/moon icons on the displays may have been counterproductive to a learning experience in three instances, as it created a semiotic dissonance, as either a sun or moon would appear when the solar panel was exposed to the light from a lamp, and it may have led them to use words and associations more linked to the images, than to the actual functions of the energy generators. For example P13 *"Wind turbine spins and it generates power. It becomes blue from the cold. air."* or P6 exclaimed that *"More heat"* was created as the sun would be displayed.

Another issue caused by the design of the displays was that a few participants had difficulty guessing what the artefact was, and some expected the EC display to have an interactive display which could be touched and then trigger some reaction in the artefact as can be seen in Figure 6.

5.4 Seeing it work

After having assembled the artefacts, the participants can finally see them at work. They blow on the turbine, or move the lamp to the solar panel and will see the EC display change. For most participants, this was a rewarding and encouraging experience, as they could see their work pay off. For some, this stage is where they would have a learning experience, when they saw it in action. Some participants were further engaged by the novelty of the changing screen. P29, for example, expressed that the favourite part was *"... especially to see it work when it was spinning."*. Most participants also understood the working principal of the display showing different images depending on the switches orientation or the direction the turbine was blown on and P24 (aged 9) even particularly mentioned polarity as the reason for it. A few participants still needed more guidance to understand what they saw and only understood it after several complete display switches. Three participants were generally less impressed by the effects and the simplicity of the displays but still understood the overall working mechanism *"It was cool that it became a sun and moon depending on the way it spins, but it didn't do much. It didn't have a lot of functions"* (P22).

Fig. 6. Child tracing image on the EC display with index finger.

5.5 Depth of learning

The exercises were designed as participatory and interactive experiences that should illustrate the functions of wind and solar power. We have found that a majority of the participants understood, or came to learn, how the energy was generated and used to power the EC displays. As participants' prior knowledge has not been consistently accounted for, we cannot make definite claims to how much they learned, and how much they already understood. With that in mind, we find that the exercises give most participants a surface understanding of the functional properties of the technology. For example, P2 explained after building the wind turbine *"Wind turbines create power. More wings spin faster and the bend in the wing gives more speed"*, however it is unclear how much knowledge was existing beforehand. The majority of the participants recognized at least one of the two artefacts, most often they recognized the wind turbine. As mentioned the previous section, some participants go through more of a learning process as they go through the stages of the exercises, as they learn with the help of the facilitator. For example P26 described the house when seeing it for the first time in the following way: *"It looks like an oven"*. With a little help, he understands how the solar panel work but doesn't quite understand the influence of the cloud, as he thinks it becomes night and the moon should come out. Here clearly we saw a confusion through the display again, which created a certain mental model in the participants.

	Yes	Maybe	No
Wind Turbine Activity	16 (55,2%)	10 (34,5%)	3 (10,3%)
Solar Activity	18 (62,1%)	9 (31,1%)	2 (6,9%)

Table 1. Results of Again-Again question for the two activities

5.6 Task complexity

We have varying feedback on the complexity of the tasks, that might be linked with participant age. The tasks were designed to be close-ended, in order to fit our allocated time frame, and our findings suggest that some participants noticed that there was less room for exploration or advancement and felt a bit discouraged. However, we have found that the average age of the participants that were bored, were higher (9.1years) than the average age of all participants (8.5 years) (we have in this context disregarded those who thought it was boring in comparison to LEGO). P15 (age 10) *"It is between boring and fun because it gets boring over time [...] Both things are fun in the beginning, but then get boring because I cannot paint it."*.

5.7 Quantitative Results

The results of the Smileyometer, align with these impressions. On a 5-point smiley scale rating from 'Awful' (1) to 'Brilliant' (5), the average was 3,97 for the wind turbine exercise with a standard deviation of SD = 0.87. And similarly 3,89 for the solar panel exercise with SD = 0.8. We could find no significant difference between age groups or gender for both exercises.

In terms of the Again-Again questionnaire we found that more than half of the children wanted to do both of the exercises again and that only around 10% were not inclined to do it again. An overview of this can be found in Table 1. All children that answered no (independent of the activity) in the again-again questionnaire voiced either boredom during- or had difficulties with the exercises.

6 DISCUSSION

First and foremost, it should be noted that we have not accounted for how much the participants learn from the exercises or how much knowledge was retained. We purely investigated the experience as the presented activities follow the LEGO Education Kit's lesson plan. Given that previous studies have established the educational value, we were more interested in how the new materials and construction activities would influence or hinder the experience.

Overall the results were rather positive, and only a minor part of the participants had problems following the construction and experimenting activities. The first bigger problem arose from the stiffness of the plastic clips, these can be mediated in multiple ways, for example by pre-bending them or asking the children to bend them several times before using them. The usage of metal round head fasteners are another alternative that would make it a bit easier to use as they are more bendable. The needed power to blow onto the wind-turbine was in some cases too high for the child, but this could be solved by using a smaller motor that requires less torque to move. Furthermore we identified other more complex and severe issues that arose during the evaluation and will discuss them below.

6.1 Mental Model of Electrochromic Displays

Two of the major issues that were encountered were a direct result of a mismatched mental model of the role of the electrochromic display. On the one side, the children assumed the display to be touch-enabled and to act as a trigger to activate the artefacts. Given the socio-cultural background of the children it can be assumed that they had prior experiences with touch enabled mobile devices and tried to apply their existing knowledge. The idea might have been further reinforced by the fact that there where completely assembled versions of the artefacts. This aspect could be mitigated by not starting with a completely assembled device. To overcome the general misconception of a touch-screen would be a bit more problematic, given the plastics that are used for the production of the displays they easily give this impression. A potential solution could be to add an extra layer that is frosted and gives less of a touch-screen impression. However, as the target audience in developing countries might be less familiar with touch screens it could also be less of an issue, but this needs to be tested and specifically to the cultural context adapted.

The second substantial issue that arose was that the graphical design was leading the participants to a mismatched mental model for the underlying principles and may have created a semiotic dissonance. While this only occurred in three instances it is still a highly problematic issue. The designs used for the displays (compare Figure 2) was meant to be a more flexible and useful for other situations as well. However, given the results, we would rather chose a clearer graphical design, for example a battery symbol. Again, these designs would need to be adapted to the social and cultural contexts (e.g. batteries might not be a symbol of energy in some regions).

Besides these two issues however, the displays worked surprisingly well. While we originally also thought about other technologies such as LED's we decided that these displays can provide clear visibility even in daylight. Furthermore, the EC displays stay in each state for a longer time so that after the children has, for example, used the wind turbine, they had enough time to observe the displays change, which would not have been possible with an LED.

6.2 Free exploration

The exercises were closed ended in order to ensure a 10 minute duration per task, and this limited the options for variation and exploration. A few participants also expressed interest in not only continuing the decoration of the house, but also specifically asking if they can paint it, even leading to one participant expressing that it became boring because they didn't have the opportunity. This is also in line with the findings of [9, 26] and clearly shows the potential for a more open-ended play situation. We are confident that the overall setup is strong enough to be adapted for open-ended play. If the time-restraints were removed, the exercises and artefacts could be further developed with a "low floor, high ceiling" approach. This has the potential of generating a longer and more fun play-experience, that facilitates deeper learning and exploration. It would also be quite possible to create mechanism or simple machines such as 4-bar linkages with the setup presented here. Similar to how the round head paper fasteners are already used in articulated paper sculptures, this would allow for additional interactivity and could enrich the possibilities.

6.3 Validity of highly positive feedback

This study was conducted in the context of LEGO World 2020 where new products are launched and special exhibits showcase existing products in new ways, i.e. full size car replica made from LEGO bricks, LEGO bricks that rain from the ceiling, etc. The study participants were recruited in the 'test area,' where kids can take part in play studies with prototypes and give feedback to the product development team. Many parents bring their children directly to this area to sign up and take part in these play studies from evaluating concept videos, play testing soon to be released construction sets, or taking part in more exploratory studies. We believe that some participants may have been disappointed that the tasks had little to do with LEGO bricks.

In spite of this, we have received generally positive feedback. When asked if they would play with the artefacts again, over half said yes to both exercises, approx. a third said maybe and about or less than a tenth said no. We find the fact that the feedback was so positive, in spite of the context of LEGO World and expectations that gave some participants, to inform on the high validity of these results. We find this to be encouraging of further development of this positive learning experience.

6.4 Data recording

Data is recorded as notes by facilitators during the exercises, and is not otherwise recorded. Therefore quotes from participants may have been abridged or simplified by facilitators, and are therefore not direct quotes. In some instances the facilitators have written the testimony of the participants in quotation marks, and in these instances we consider it to be, if not direct quotes, at least a paraphrased quote that closely represents the participants' statements. There are also some some quotes and sentiments that stand as independent statements, but may have been prompted by questions, and not stated on the participants own initiative. For example, the facilitator would ask what the participant liked about the artefacts, and they would respond "I like the colours" as a response, not as an independently occurring statement.

6.5 Demographics and Subject Matter Knowledge

While we did not ask parents or children about their socio-economic situations, education or professional background of parents, the participants in this study were attendees at the LEGO World event, thus, could afford the cost of admission to the event. Furthermore, parents accompanied their children and chose to sign up for the study focused on power generation, which may indicate receptivity and interest in the subject matter. The event took place in Copenhagen, the capital of Denmark, which has wide support and awareness in childhood education of issues related to climate change and sustainable energy [7]. Thus, we assume the children were likely to be somewhat familiar with the topics and materials, e.g the solar panel. In future studies, we are interested in how participants from a wider cross-section of backgrounds and demographic factors might yield different results. There is, furthermore, a significant lack of female participant in this study, this is perhaps due to the demographic of LEGO World attendees or pre-selection of participants. For this reason, it is not representative of how gender could affect the results and we have little indication of whether female participants would have significantly different responses.

7 CONCLUSION & FUTURE WORK

In this paper we explored how cheap, low-cost materials and simple electrochromic displays can be designed to support experiential learning about energy and power generation. For this, we employed a mix of open-ended play and exploration as well as staged goal-oriented activities. We developed two learning activities that involve children constructing working models that generate power including constructing a wind turbine and assembling a solar power harvesting house. The results of our study demonstrate that the children were overall capable of constructing the artefacts, understood the building mechanisms, were able to infer the power production part and in general were positive about the experience. We identified challenges encountered by the children including interactions with the construction materials and electrochromic screens as well as insights about the mental models that children had for understanding the prototypes.

In the future we would like to extend the evaluation to more formal and informal settings such as part of normal school curricula. However, the main focus will on exploring how it can be adapted for children and schools in developing countries. We will explore how to adapt the construction activities for the socio-cultural contexts as well as including locally sourced materials for the construction and assembly that can be found in the respective regions.

8 SELECTION AND PARTICIPATION OF CHILDREN

The evaluation was carried out at the LEGO® World 2020 exhibition in Copenhagen, Denmark. This event happened in February before the COVID-19 pandemic. While the evaluation did not happen in a public area, a poster was visible in the main expo area with a pictorial explanation of the activity. Next to this poster the parents were required to sign a consent form if they wanted to their child to take part in the study. The parents were provided with information sheets outlining the aims of the study, the data that would be collected and how this data would be used. After that they would get a specific time slot when they had to come back and accompany their child to the testing area. The children were informed about the studies in simplified language on the way to the study area where the study facilitators would slowly prepare the children for the study and also discuss their experiences at LEGO World so far and slowly get acquainted with the children.

ACKNOWLEDGMENTS

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 760973. Furthermore, we would also like to thank our collaborators from the LEGO Foundation for supporting this study.

REFERENCES

[1] Konstantin Aal, George Yerousis, Kai Schubert, Dominik Hornung, Oliver Stickel, and Volker Wulf. 2014. Come_in@palestine: Adapting a German Computer Club Concept to a Palestinian Refugee Camp. In *Proceedings of the 5th ACM International Conference on Collaboration across Boundaries: Culture, Distance & Technology* (Kyoto, Japan) *(CABS '14)*. Association for Computing Machinery, New York, NY, USA, 111–120. https://doi.org/10.1145/2631488.2631498

[2] Sibel Acisli. 2017. The investigation of the effects of robotic-assisted practices in teaching renewable energy sources to seventh-grade students in secondary school. *The Eurasia Proceedings of Educational & Social Sciences* 6 (2017), 167–172.

[3] Velayudhan Alekh, Vilvanathan Vennila, Rahul Nair, Vattigunta Susmitha, Anirudh Muraleedharan, Meltem Alkoyak-Yildiz, Nagarajan Akshay, and Rao R. Bhavani. 2018. Aim for the Sky: Fostering a Constructionist Learning Environment for Teaching Maker Skills to Children in India. In *Proceedings of the Conference on Creativity and Making in Education* (Trondheim, Norway) *(FabLearn Europe'18)*. Association for Computing Machinery, New York, NY, USA, 87–94. https://doi.org/10.1145/3213818.3213830

[4] Tim Bell and Jan Vahrenhold. 2018. CS unplugged—how is it used, and does it work? In *Adventures between lower bounds and higher altitudes*. Springer, 497–521.

[5] Paulo Blikstein and Dennis Krannich. 2013. The Makers' Movement and FabLabs in Education: Experiences, Technologies, and Research. In *Proceedings of the 12th International Conference on Interaction Design and Children* (New York, New York, USA) *(IDC '13)*. Association for Computing Machinery, New York, NY, USA, 613–616. https://doi.org/10.1145/2485760.2485884

[6] Guy A. Boy. 2013. From STEM to STEAM: Toward a Human-centred Education, Creativity, Learning Thinking. In *Proceedings of the 31st European Conference on Cognitive Ergonomics* (Toulouse, France) *(ECCE '13)*. ACM, New York, NY, USA, Article 3, 7 pages. https://doi.org/10.1145/2501907.2501934

[7] Soren Breiting and Per Wickenberg. 2010. The progressive development of environmental education in Sweden and Denmark. *Environmental Education Research* 16, 1 (Feb. 2010), 9–37. https://doi.org/10.1080/13504620903533221 Publisher: Routledge _eprint: https://doi.org/10.1080/13504620903533221.

[8] Sharon Lynn Chu, Genna Angello, Michael Saenz, and Francis Quek. 2017. Fun in Making: Understanding the experience of fun and learning through curriculum-based Making in the elementary school classroom. *Entertainment Computing* 18 (2017), 31–40.

[9] Sharon Lynn Chu, Francis Quek, Sourabh Bhangaonkar, Amy Boettcher Ging, and Kumar Sridharamurthy. 2015. Making the Maker: A Means-to-an-Ends approach to nurturing the Maker mindset in elementary-aged children. *International Journal of Child-Computer Interaction* 5 (2015), 11–19.

[10] Norman K. Denzin and Yvonna S. Lincoln (Eds.). 2018. *The SAGE handbook of qualitative research* (fifth edition ed.). SAGE, Los Angeles London New Delhi Singapore Washington DC Melbourne. OCLC: 990795722.

[11] Eva Eriksson, Ole Sejer Iversen, Gökçe Elif Baykal, Maarten Van Mechelen, Rachel Smith, Marie-Louise Wagner, Bjarke Vognstrup Fog, Clemens Klokmose, Bronwyn Cumbo, Arthur Hjorth, et al. 2019. Widening the scope of fablearn research: Integrating computational thinking, design and making. In *Proceedings of the FabLearn Europe 2019 Conference*. 1–9.

[12] Scott Freeman, Sarah L Eddy, Miles McDonough, Michelle K Smith, Nnadozie Okoroafor, Hannah Jordt, and Mary Pat Wenderoth. 2014. Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences* 111, 23 (2014), 8410–8415.

[13] Çağlar Genç, Ashley Colley, Markus Löchtefeld, and Jonna Häkkilä. 2020. Face Mask Design to Mitigate Facial Expression Occlusion. In *Proceedings of the 2020 International Symposium on Wearable Computers* (Virtual Event, Mexico) *(ISWC '20)*. Association for Computing Machinery, New York, NY, USA, 40–44. https://doi.org/10.1145/3410531.3414303

[14] Walther Jensen, Ashley Colley, Jonna Häkkilä, Carlos Pinheiro, and Markus Löchtefeld. 2019. TransPrint: A Method for Fabricating Flexible Transparent Free-Form Displays. *Advances in Human-Computer Interaction* 2019 (2019).

[15] Walther Jensen, Ashley Colley, and Markus Löchtefeld. 2019. VitaBoot: Footwear with Dynamic Graphical Patterning. In *Proceedings of the 23rd International Symposium on Wearable Computers* (London, United Kingdom) *(ISWC '19)*. Association for Computing Machinery, New York, NY, USA, 279–283. https://doi.org/10.1145/3341163.3346937

[16] Walther Jensen, Hendrik Knoche, and Markus Löchtefeld. 2020. "Do You Think It is Going to Be the Cock?": Using Ambient Shadow Projection in Dialogic Reading. In *Proceedings of the 9TH ACM International Symposium on Pervasive Displays* (Manchester, United Kingdom) *(PerDis '20)*. Association for Computing Machinery, New York, NY, USA, 97–103. https://doi.org/10.1145/3393712.3395342

[17] Walther Jensen, Markus Löchtefeld, and Hendrik Knoche. 2019. ShadowLamp: An Ambient Display with Controllable Shadow Projection Using Electrochromic Materials.. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–6. https://doi.org/10.1145/3290607.3313011

[18] Walther Jensen, Thomas Streubel Kristensen, Christoffer Sand Kirk, Hassan Abdul Hameed, Daniel Bergmann Villadsen, and Markus Löchtefeld. 2020. Hybrid Settlers - Integrating Dynamic Tiles into a Physical Board Game Using Electrochromic Displays. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems* (Honolulu, HI, USA) *(CHI EA '20)*. Association for Computing Machinery, New York, NY, USA, 1–7. https://doi.org/10.1145/3334480.3382857

[19] Myounghoon Jeon, Maryam FakhrHosseini, Jaclyn Barnes, Zackery Duford, Ruimin Zhang, Joseph Ryan, and Eric Vasey. 2016. Making Live Theatre with Multiple Robots As Actors: Bringing Robots to Rural Schools to Promote STEAM Education for Underserved Students. In *The Eleventh ACM/IEEE International Conference on Human Robot Interaction* (Christchurch, New Zealand) *(HRI '16)*. IEEE Press, Piscataway, NJ, USA, 445–446. http://dl.acm.org/citation.cfm?id=2906831.2906919

[20] Eva-Sophie Katterfeldt, Nadine Dittert, and Heidi Schelhowe. 2009. EduWear: Smart Textiles As Ways of Relating Computing Technology to Everyday Life. In *Proceedings of the 8th International Conference on Interaction Design and Children* (Como, Italy) *(IDC '09)*. ACM, New York, NY, USA, 9–17. https://doi.org/10.1145/1551788.1551791

[21] David A Kolb. 2014. *Experiential learning: Experience as the source of learning and development.* FT press.

[22] Stacey Kuznetsov, Piyum Fernando, Emily Ritter, Cassandra Barrett, Jennifer Weiler, and Marissa Rohr. 2018. Screenprinting and TEI: Supporting Engagement with STEAM Through DIY Fabrication of Smart Materials. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction* (Stockholm, Sweden) *(TEI '18)*. ACM, New York, NY, USA, 211–220. https://doi.org/10.1145/3173225.3173253

[23] Markus Löchtefeld, Walther Jensen, Heiko Müller, and Ashley Colley. 2019. Prototyping Transparent and Flexible Electrochromic Displays. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems* (Glasgow, Scotland Uk) *(CHI EA '19)*. Association for Computing Machinery, New York, NY, USA, 1–4. https://doi.org/10.1145/3290607.3298827

[24] Leilah Lyons, Michael Tissenbaum, Matthew Berland, Rebecca Eydt, Lauren Wielgus, and Adam Mechtley. 2015. Designing Visible Engineering: Supporting Tinkering Performances in Museums. In *Proceedings of the 14th International Conference on Interaction Design and Children* (Boston, Massachusetts) *(IDC '15)*. Association for Computing Machinery, New York, NY, USA, 49–58. https://doi.org/10.1145/2771839.2771845

[25] Margaret E Madden, Marsha Baxter, Heather Beauchamp, Kimberley Bouchard, Derek Habermas, Mark Huff, Brian Ladd, Jill Pearon, and Gordon Plague. 2013. Rethinking STEM education: An interdisciplinary STEAM curriculum. *Procedia Computer Science* 20 (2013), 541–546.

[26] Thomas W. Malone. 1980. What Makes Things Fun to Learn? Heuristics for Designing Instructional Computer Games. In *Proceedings of the 3rd ACM SIGSMALL Symposium and the First SIGPC Symposium on Small Systems* (Palo Alto, California, USA) *(SIGSMALL '80)*. ACM, New York, NY, USA, 162–169. https://doi.org/10.1145/800088.802839

[27] David A. Mellis, Sam Jacoby, Leah Buechley, Hannah Perner-Wilson, and Jie Qi. 2013. Microcontrollers as Material: Crafting Circuits with Paper, Conductive Ink, Electronic Components, and an "Untoolkit". In *Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction* (Barcelona, Spain) *(TEI '13)*. Association for Computing Machinery, New York, NY, USA, 83–90. https://doi.org/10.1145/2460625.2460638

[28] Heiko Müller, Ashley Colley, Jonna Häkkilä, Walther Jensen, and Markus Löchtefeld. 2019. Using Electrochromic Displays to Display Ambient Information and Notifications. In *Adjunct Proceedings of the 2019 ACM International Joint Conference on Pervasive and Ubiquitous Computing and Proceedings of the 2019 ACM International Symposium on Wearable Computers* (London, United Kingdom) *(UbiComp/ISWC '19 Adjunct)*. Association for Computing Machinery, New York, NY, USA, 1075–1078. https://doi.org/10.1145/3341162.3344844

[29] Seymour Papert. 1986. *Constructionism: A new opportunity for elementary science education.* Massachusetts Institute of Technology, Media Laboratory, Epistemology and . . . .

[30] Jie Qi, Leah Buechley, Andrew "bunnie" Huang, Patricia Ng, Sean Cross, and Joseph A. Paradiso. 2018. Chibitronics in the Wild: Engaging New Communities in Creating Technology with Paper Electronics. In *Proceedings of the 2018 CHI Conference on Human Factors in Computing Systems* (Montreal QC, Canada) *(CHI '18)*. Association for Computing Machinery, New York, NY, USA, 1–11. https://doi.org/10.1145/3173574.3173826

[31] Kanjun Qiu, Leah Buechley, Edward Baafi, and Wendy Dubow. 2013. A Curriculum for Teaching Computer Science Through Computational Textiles. In *Proceedings of the 12th International Conference on Interaction Design and Children* (New York, New York, USA) *(IDC '13)*. ACM, New York, NY, USA, 20–27. https://doi.org/10.1145/2485760.2485787

[32] Janet Read and Stuart Macfarlane. 2002. Endurability, Engagement and Expectations: Measuring Children's Fun. In *Interaction Design and Children, Shaker Publishing*. Shaker Publishing, 1–23.

[33] Janet C. Read and Stuart MacFarlane. 2006. Using the Fun Toolkit and Other Survey Methods to Gather Opinions in Child Computer Interaction. In *Proceedings of the 2006 Conference on Interaction Design and Children* (Tampere, Finland) *(IDC '06)*. Association for Computing Machinery, New York, NY, USA, 81–88. https://doi.org/10.1145/1139073.1139096

[34] Mitchel Resnick. 2006. Computer as paint brush: Technology, play, and the creative society. *Play= learning: How play motivates and enhances children's cognitive and social-emotional growth* (2006), 192–208.

[35] Stella Timotheou and Andri Ioannou. 2019. On Making, Tinkering, Coding and Play for Learning: A Review of Current Research. In *IFIP Conference on Human-Computer Interaction*. Springer, 217–232.

[36] Leena Ventä-Olkkonen, Heidi Hartikainen, Behnaz Norouzi, Netta Iivari, and Marianne Kinnula. 2019. A literature review of the practice of educating children about technology making. In *IFIP Conference on Human-Computer Interaction*. Springer, 418–441.

[37] Shirin Vossoughi, Paula K Hooper, and Meg Escudé. 2016. Making through the lens of culture and power: Toward transformative visions for educational equity. *Harvard Educational Review* 86, 2 (2016), 206–232.

[38] Anne Weibert, Andrea Marshall, Konstantin Aal, Kai Schubert, and Jennifer Rode. 2014. Sewing Interest in E-textiles: Analyzing Making from a Gendered Perspective. In *Proceedings of the 2014 Conference on Designing Interactive Systems* (Vancouver, BC, Canada) *(DIS '14)*. ACM, New York, NY, USA, 15–24. https://doi.org/10.1145/2598510.2600886

[39] Anne Weibert, Marios Mouratidis, Renad Khateb, Sarah Rüller, Miriam Hosak, Shpresa Potka, Konstantin Aal, and Volker Wulf. 2017. Creating Environmental Awareness with Upcycling Making Activities: A Study of Children in Germany and Palestine. In *Proceedings of the 2017 Conference on Interaction Design and Children* (Stanford, California, USA) *(IDC '17)*. Association for Computing Machinery, New York, NY, USA, 286–291. https://doi.org/10.1145/3078072.3079732