Programming Jewelry: Revealing Models behind Digital Fabrication

Nadine Dittert
Digital Media in Education
dimeb, TZI
Dep. of Computer Science
University of Bremen, Germany
ndittert@tzi.de

Eva-Sophie Katterfeldt
Digital Media in Education
dimeb, TZI
Dep. of Computer Science
University of Bremen, Germany
evak@tzi.de

Sabrina Wilske
Digital Media in Education
dimeb, TZI
Dep. of Computer Science
University of Bremen, Germany
wilske@tzi.de

Abstract
Digital fabrication technologies offer potential for sustainable learning by making models behind digitally fabricated artifacts graspable. Thus, we present a workshop concept that combines programming of graphics with laser cutting and engages children in designing, programming and fabricating jewelry. We report on our findings and conclude with recommendations and challenges to be considered in future workshops and research.

Author Keywords
FabLab, digital fabrication, laser cutter, Processing, education, children

ACM Classification Keywords
K.3.2 [Computer and Information Science Education]: Literacy.

Introduction
Programming graphics as a subject for children's education in computational thinking has a long history. This concept was implemented in Papert's turtle graphics LOGO [3], which was among the first programming applications for children. In recent years, programming applications targeted at kids have put more emphasis on interactive aspects [4]. With the rise of modern fabrication machines for everyone such as laser cutters, which require vector graphic images, programming of graphics gains new relevance. Tools available in FabLabs offer potential for

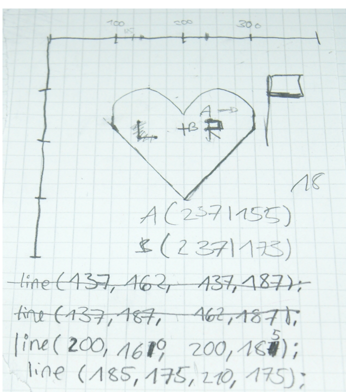

Figure 1: Sketch for a heart medallion.

learning, e.g. by combining physical activity and abstract thinking and "revealing the model behind the scene" in order to provide for deep sustainable learning also referred to as "Bildung" [6, p. 98/99]. In FabLabs, digital models can be transformed into graspable objects. But from our point of view these potentials are not yet fully tapped. Common drawing or 3d modeling applications hide the basic principles and models behind the software [7]. For FabLabs, graphics applications such as Inkscape[1] are valuable because they are freely available. However, they are not very transparent, and people can become frustrated because their mental model doesn't necessarily match with the one the software interface implements. Simply using such software does not sufficiently facilitate the sort of deep sustainable learning about core concepts of digital media and computational thinking which we see as prerequisites for empowered citizens in 21st century society.

In our work, we attempt to develop approaches that reveal the functioning of software technology and allow the users to get a deeper insight. To this end, we developed a workshop concept where digital fabrication is addressed through programming in Processing[2] to create input for a laser cutter. A similar approach to use Processing and laser cutting for young people is presented in [2], it differs from ours in that is allows for more sophisticated patterns that require more complex coding.

Our workshop concept is based on the TechKreativ concept [1], which seeks to combine technology with creative design. The approach is rooted in Constructionism [3] and its main premises are encouraging children's fantasy, relating to children's experiences and empowering them to master new concepts themselves. Following these principles, by focusing on basic shapes, we wanted to use as few code commands as possible so that the participants fully understood the code. For the concept it was important that the children had an ongoing sense of achievement. Thus, we sought to keep them motivated and empowered throughout all steps of the workshop – beginning with their first programming attempts and concluding with the completed piece of jewelry.

Programming Jewelry: The Workshop

The *EduFab* project aims at providing concepts on how to embed FabLab technologies into school curricula for STEAM subjects[3]. The Programming Jewelry workshop was a three-hour event within this project where eleven girls aged 13 and 14 years programmed their own jewelry and cut it with the laser cutter. The workshop was part of the German *Girls' Day*, which is a national event to encourage girls take a look into careers that are traditionally male dominated.[4] None of the girls had programmed before. Three researchers helped with programming and cutting the objects.

The workshop started with a brief introduction to FabLabs: What is a FabLab? What and who is it for? How can I use it? Following this, the laser-cutter was explained in its general functionality by drawing parallels to magnifying lenses and their power to burn things using light rays. The cutting process was explained by drawing an analogy to printing files on paper. Then, we gave a short introduction to programming. We used Processing as programming language since it is suitable for novices ("low floor" [5]) and it allows for a straightforward output to pdf-files which are suitable input for the laser cutter.

Programming was introduced starting from a blank main Processing window. We started changing the size and the

[1] http://www.inkscape.org last access 05/2014
[2] http://processing.org last access 05/2014
[3] http://dimeb.de/edufab last access 05/2014
[4] http://www.girls-day.de/english last access 05/2014


```
import processing.pdf.*;

size(400,400);
background(255);

beginRecord(PDF, "muster.pdf");

arc(150,150, 100,100, PI,PI*2);
arc(250,150, 100,100, PI,PI*2);
line(100,150, 100,175);
line(300,150, 300,175);
line(100,175, 200,300);
line(300,175, 200,300);

line(137,155, 137,187);
line(137,187, 162,187);

line(200,165, 200,185);
line(190,175, 210,175);

//line(237,155, 255,155);
//line(255,155, 255,173);
//line(255,173, 237,173);
line(237,173, 255,187);

arc(237,164, 25,25, -0.5*PI,0.5*PI);

line(237,155, 237,187);

endRecord();
```

Figure 2: Programming code for the heart medallion.

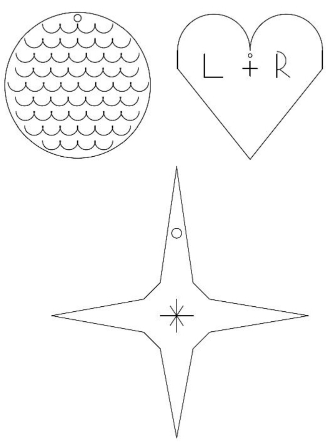

Figure 3: Graphic patterns that the girls programmed in the workshop.

background of the display window which was all we needed for our purpose. The display window was explained by comparing it to a school's coordinate system which the girls were familiar with. We started to draw lines using the `line()` command which draws lines from one point to another, where both points are specified by their x and y coordinates. The girls were then asked to start programming on their own by trying to draw two crossing lines. This task was completed without problems. Further, we explained how to use for-loops in order to repeat commands easily and to create patterns. We had handouts prepared where the girls could also find how to draw rectangles, circles, ellipses and arcs as well as the syntax of for-loops. Three lines of code that were necessary to create the pdf-files were shown right before cutting started, but were not further explained.

In groups of two, the girls created stars, a fish pattern, a heart and letters (fig. 3) that were all coded using the basic code lines mentioned above (fig. 2). All girls decided to create a necklace with their artifact, although we provided different material to create earrings, necklaces or other accessories. Fig. 4 shows an example of a created piece.

Findings

The workshop was accompanied by four researchers (three of them also acting as tutors) using contextual inquiry. Afterwards, the children filled out questionnaires concerning how they liked the workshop. After the workshop, each researcher noted her observations individually on cards and we sorted and discussed them together. Also the artifacts created (including sketches and programs) were considered. Our main objectives were to find out whether the combination of programming, digital crafting and creative design was engaging enough, and if and how the participants were able to create digital models of their ideas by means of programming.

All groups made sketches of their design on paper (see Fig. 1) which they translated into Processing code. We observed that the participants showed full control and confidence in mastering the program commands to realize their designs. From a comparison of the initial sketches and final artifacts, we conclude that they succeeded in digitizing their ideas through mindful programming. They applied their mathematical knowledge extensively while calculating the coordinates for their drawings. That way, they found the means to create letters and patterns using only lines and arcs, which we had not expected. They programmed very autonomously and needed little help from the tutors. Programming was done in a considered and logical manner and we did not observe much trial-and-error programming. Apart from minor attempts, the girls did not make use of for-loops. It seemed that this concept was still too complex for first-time programmers to apply in a 3 hour workshop. In general, all participants were actively engaged and focused throughout the workshop.

According to the questionnaires, the most popular aspects of the workshop were the opportunities to create something (40%), to program (30%), and to use the laser cutter (17%)(free response question). From these results we conclude that the combination of computational activities with creative design and fabrication was well balanced and appreciated by the participants.

We observed challenges related to laser cutting. Due to time constraints, the preparation and dispatch of the files to the cutter still had to be done by a tutor. For the girls, this remained an opaque and uncontrollable step in the production process. The cutting process resulted in waiting queues and, due to the limited time of this short workshop, did not allow for iterative design cycles. According to the questionnaire, the waiting time was the least popular aspect of the workshop, mentioned by 64% of the

Figure 4: Laser cut jewelry: Prototype earring (made by tutors, programmed with for-loops) and the cut out heart medallion.

participants in a free response question.

We would like to share some practical findings in order to facilitate similar projects and to build upon our experiences: It proved useful to provide small squared paper for paper prototyping and sketching. The number of participants is constrained by the available machinery: in our case 6 groups could have their designs cut and engraved in the given time frame on one laser cutter; more participants would have required more machines or more time. The cutting process can be further streamlined by providing only a single option for the material, as switching between different materials requires re-adjusting of the cutter.

Conclusion and future work

This workshop provides an example of how we can unveil digital models in working with digital fabrication machines. The concept combines the design and crafting of personally meaningful objects with computer science concepts, enabling the participants to create the computational models behind digital graphics on their own. We would like to see more initiatives that try to uncover computational models in – and by means of – digital fabrication. Besides the promising experience, the benefits of digital fabrication machines over previous technologies for learning of computational concepts need to be reflected on in more depth.

For future work, we want to extend the concept to longer workshops that leave time for more iterative design cycles. We also want to modify the programming introduction to encourage the use of iterative programming concepts like for-loops to allow for repetitive shapes, highlighting the concept of automation and reproducibility, which is a crucial part of digital fabrication and manufacturing itself. We also plan to bring other digital technologies in, e.g. using sensor data from physical computing projects to create and modify shapes for laser cutting and 3D printing.

Acknowledgements

We thank all participants and FabLab Bremen e.V. The project *EduFab* is funded by the German Federal Ministry of Education and Research (BMBF).

References

[1] Dittert, N., Dittmann, K., Grüter, T., Kümmel, A., Osterloh, A., Reichel, M., Schelhowe, H., Volkmann, G., and Zorn, I. Understanding digital media by constructing intelligent artefacts - design of a learning environment for children. In *Proc. of ED-MEDIA*, AACE (2008), 2348–2358.

[2] Jacobs, J., and Buechley, L. Codeable objects: Computational design and digital fabrication for novice programmers. In *Proc. of CHI*, ACM (2013), 1589–1598.

[3] Papert, S. *Mindstorms: children, computers, and powerful ideas*. Basic Books, New York, NY, 1980.

[4] Resnick, M., Maloney, J., Monroy-Hernndez, A., Rusk, N., Eastmond, E., Brennan, K., Millner, A., Rosenbaum, E., Silver, J., Silverman, B., and Kafai, Y. Scratch: Programming for all. *Commun. ACM 52*, 11 (Nov. 2009), 60–67.

[5] Resnick, M., and Silverman, B. Some reflections on designing construction kits for kids. In *Proc. of IDC*, ACM (New York, NY, 2005), 117–122.

[6] Schelhowe, H. Digital realities, physical action and deep learning - FabLabs as educational environments? In *FabLab - Of Machines, Makers and Inventors*. Transcript, 2013.

[7] Zeising, A., Katterfeldt, E.-S., and Schelhowe, H. Considering constructionism for digital fabrication software design. In *Position Paper at Digital Fabrication in Education Workshop at IDC 2013* (NY, 2013). http://tinyurl.com/ekdimeb/pub/df2013.pdf.