Chapter 4
Makerspace Methodologies & Design Principles

The *four FemTech design principles* which underscore all our work are that design artefacts must (1) produce alternative narratives of computer science, which (2) challenge the taken-for-granted assumptions about computer science, by (3) embedding a story into the design while (4) allowing for surprising interactive opportunities. However, before we dive into the details of these principles, we contextualize the principles in the design practices by which they were made.

Makerspace Methodologies

FemTech.dk is fundamentally about unpacking the phenomenon of gender representation in computer science, with the aim of creating interventions through design artefacts. Thus, the process by which the design artefacts are produced is important for understanding our work – a design process guided by the FemTech.dk design principles that form the basis of our artefacts.

In this chapter, we provide more details about the contextual design situations in which we have worked. These design situations were characterized by technological choices, physical spaces, and events. Then, we introduce the design principles that serve as the foundations for our work. We hope that both the contextual situations and the design principles can assist others in creating their own initiatives and interventions, transforming gender representation in computing.

First, it is important to state that when we began our work, we shared an interest in creating design artefacts that combined physical and digital properties – and we were inspired by the amazing work of researchers such as Daniela Rosner, Nadya Peek, Morgan Ames, Silvia Lindtner, Amanda Williams, Leah Buckley, Audrey Desjardin, Shaowen Bardzell, and Verena Fuchsberger, to mention just a few (Buechley et al. 2008; Bardzell et al. 2012; Tanenbaum et al. 2013; Wakkary et al. 2013; Ames et al. 2014; Rosner et al. 2014; Fox et al. 2015; Fuchsberger et al. 2015, 2016; Peek et al. 2017; Rosner et al. 2018a, b). Each of these researchers has their

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own individual ways of creating their unique and novel research, yet they share a dedication to understanding design practices in various contexts, places, and communities – and have in important ways influenced how we can think and practice design and development of digital technologies, as well as how to make creative spaces (e.g., makerspaces, and fablabs) and artefacts that demonstrate counter-political concerns and challenging narratives.

Our research interest aligns well with the above agenda, and part of our work has focused on creating a space – a makerspace – at the university. The vision for the makerspace was to have a place both that could drive change for the perception of computing but also where we could work with participants and students, inviting them into the interventionist activities of design.

UPCH Makerspace as a Concept

In 2016 there was no makerspace or anything similar at the University of Copenhagen, so one of the first initiatives was to see whether we could pilot a MakerWeek as part of our teaching in Fall 2016 and use the insights to mobilize diverse researchers across the university in 2017 to see what we could accomplish (Bjørn and Hornbæk 2017). Simultaneously, we identified all the makerspaces, hackerspaces, fablabs, and so forth located in the Copenhagen area at that time to see which connections we could make outside the university as well (Lundberg et al. 2017; Menendez-Blanco and Bjørn 2019). This work allowed us to define a strategy for conceptualizing a makerspace at the university and to begin as a small grassroots community. We used the UCPH makerspace concept early on to create a Facebook page as well as a website about activities and ideas. This digital presence allowed us to engage in activities despite having no physical facilities. The physical manifestation of the makerspace at this time was plastic boxes with electronics in our offices or borrowed 3D printers which we transported to the SCIENCE library (KUBNord) to set up for the MakerWeek (Fig. 4.1).

At this time, the practical circumstances for engaging in activities in the makerspace made our activities cumbersome and required a lot of resources and flexibility to adapt to changing circumstances. Over the years, we were able to secure a physical space, where we also included bachelor's and master's thesis students in our efforts. The space began as a shared space between Computer Science, the Department of Information Science, and the Department of Communication at the Southern campus. We were also able to raise funds to help set up a component library at the makerspace. At this time, part of the Department of Computer Science was also located at the Southern campus; however, the entire department was moved to the Northern campus in 2018. Although we moved our offices, the makerspace stayed at the Southern campus and gained more resources over time. We, however, continue our efforts towards establishing a makerspace at the Northern campus as well.

Fig. 4.1 MakerWeek preparation and execution

While the UCPH Makerspace concept created a physical and digital context for our design practices, what was even more important was that in our work we wanted to challenge the assumptions and characteristics of computer science as a field, profession, and practice that were centered around screens and keyboards. We wanted to find new ways to demonstrate how computer science and the artefacts produced could be interactive by mixing digital and physical materials. We wanted to move the representation of computer science from a practice directed at creating digital applications for use on traditional digital devices such as smartphones, tablets, laptops, or desktops to exposure as a practice that can also engage in creative design practices embedding technology in the physical world. Such representations indeed exist, but they were not visible initially in the computer science narrative at our university. We wanted to change how computer science is perceived at the University of Copenhagen: not solely as a desktop activity but also requiring lab facilities. Thus, a core design decision we made early on was to focus our technology choices on micro-controllers and electronics – since this allowed us to clearly create artefacts combining digital and physical functionalities and thereby challenge the predominant narrative of computer science in our institution.

Micro-controllers are small computers, such as Arduino, that can be embedded in physical materials, such as textiles, and connected with other devices or the Internet. To allow for extended potentials for designing interactions, we decided to work with Internet-enabled micro-controllers; this choice enabled us to center our design artefacts on the technological concept of the Internet-of-Things (IoT). Concretely, we explored the different technical opportunities and ended by choosing the ESP8266 micro-controller (SparkFun Thing Dev Board ESP8266) as our main micro-controller. The ESP8266 was chosen because of its size, price, and robustness – and because programming could be done using the well-documented Arduino IDE (Fig. 4.2).

In designing the interaction of the artefacts, we also wanted to explore and play around with materials and physical interactions that challenged ordinary touch-screen and keyboard interactions. This made us explore and experiment with different materials such e-textiles and origami paper, as well as different kinds of interaction sensors and actuators such as motion sensors, accelerometers, and

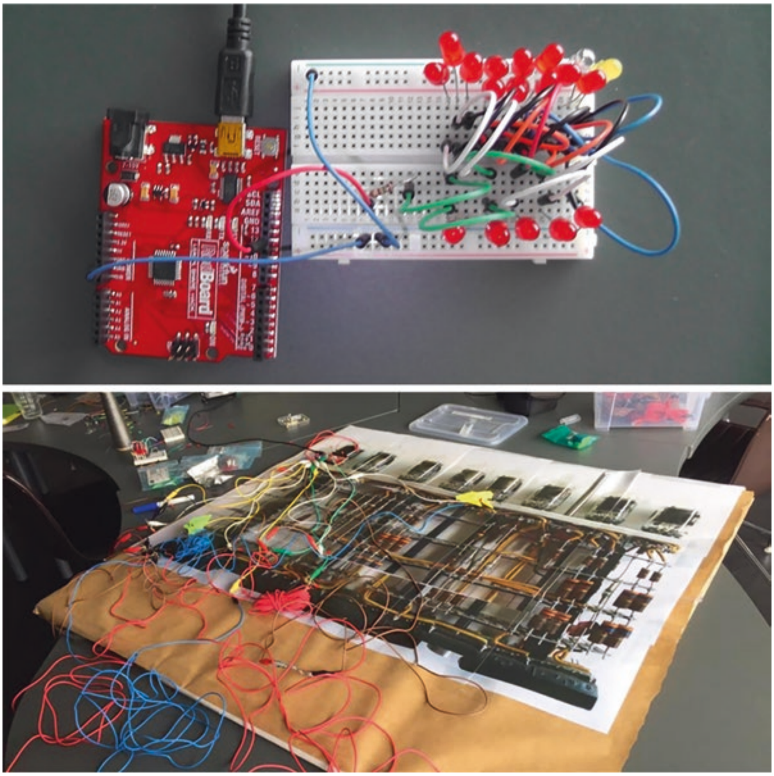

Fig. 4.2 Arduino experimentation

gyroscopes. These different electronics became the technological foundation for our activities both for the FemTech.dk design artefacts and for the opportunities we created for students to join the makerspace.

Similar to the FemTech interventions, our purpose when creating design artefacts is not only to develop an artefact but also to reflect the FemTech principles in *the process* by which artefacts are created. Thus, having a makerspace concept allowed us to invite participants to join our design activities and take part in locally producing new perspectives on computer science. Having a makerspace was especially important for the ways we ended up designing the activities. The main activities we developed were the FemTech.dk workshops, the public events, and the conceptual work for the later kick-starter course for new computer science students created by our colleague Martin Dybdal.

Concrete Interventions

We conducted the first FemTech workshop in April 2016, and since then the workshops have been a yearly event. Since 2018 the workshops have been mainstreamed, developed, and organized by other people in the department based on the same principles. Further, participation has expanded, and in 2021, the workshop was held online because of the COVID-19 pandemic and was open to more than 100 participants invited from all high schools in mainland Denmark, Greenland, and the Faroe Islands.

The kick-starter course was introduced in 2018 as a voluntary opportunity for new students who had just been accepted to the bachelor's degree program in computer science. Enrolled students are invited for a two-week intensive kick-starter course where they learn basic programming and get to know other students. One motivation for the course was to address the empirical observation that while Danish 15-year-old school youth have *the same level* of ICT skills and competences based on actual accomplishments, Danish girls still assess their own skills as lower than boys (Bundsgaard et al. 2018). This mean that the difference between young girls' *actual* computing skills and *perceived* computing skills risks impacting youth choice, since they might question whether they can succeed if pursuing an education in computer science. By offering a kick-starter course specifically aimed at new bachelor's students without prior programming experience, we wanted to demonstrate that one can start and be successful in the program without such experience. The course was open to everyone, and its structure was designed to foster collaboration and engagement between students.

The kick-starter course is a returning event and has grown in enrollment; in 2021, 120 students joined of the more than 400 students enrolled in the computer science bachelor's program. The course builds on the same principles as the FemTech workshops. Further, we are currently discussing how to bring the same principles to ordinary teaching in the computer science program, and dedicated, hands-on

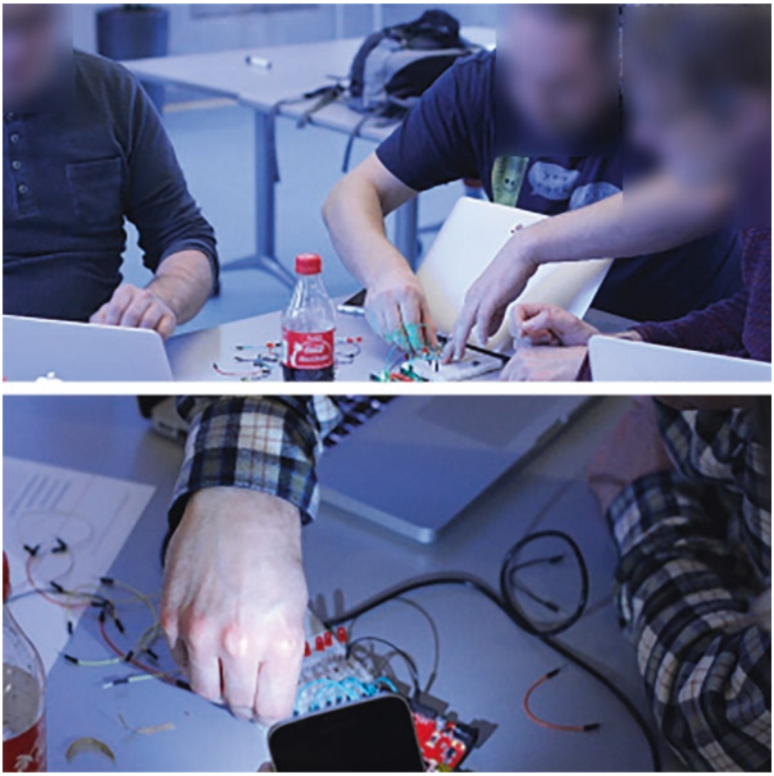

Fig. 4.3 Workshop with faculty in the Department

activities have been held with the members of the department to demonstrate their possibilities (Fig. 4.3).

It is beyond our scope here to explore the details of the kick-starter course or current efforts to be included in ordinary teaching; however, what is important is that ideas and concepts developed as part of FemTech are moving beyond FemTech activities, and efforts are invested in normalizing the principles for ordinary teaching in computer science. In the following chapters, we focus on the details of three FemTech design artefacts: Cyberbear, Cryptosphere, and GRACE; however, before we turn to these, we want to make explicit the design principles.

The Four FemTech Design Principles

The *four FemTech design principles* stipulate that design artefacts must (1) challenge the taken-for-granted assumptions about computer science and (2) produce alternative narratives of computer science, by (3) embedding a story into the design while (4) allowing for interactive opportunities that trigger curiosity. Let's unpack each of these.

Challenging Taken-for-Granted Assumptions

Design artefacts must challenge the taken-for-granted assumptions about computer science in the local context. The first principle guides the design process to explicitly address taken-for-granted assumptions about computer science in the specific context of intervention. Such assumptions about computing can take many different forms, and in our case the focus for our designs has been on *materials* and *interaction*. The materiality of computing artefacts is often viewed as merely digital, as these are structured as 0 s and 1 s. Interestingly, digital online artefacts (such as e-books, gaming worlds, and interactive websites) are not solo digital entities but instead depend on material properties and physical infrastructure such as fiberoptic cables and server farms (Dourish 2017), and we wanted to make these physical properties visible in our digital design. We wanted to emphasize the physical experience of digital interaction through physical manifestation in the artefacts. This meant that when we designed our artefacts, we needed to explicitly and reflectively experiment with and use materials that were often not connected to digital interaction. The material matter that produces the artefacts should through choice of material challenge taken-for-granted assumptions about the material matter of digital devices. Concretely, we experimented with many different materials in our design processes – and in the end each of the three FemTech design artefacts presented in this book are based on a different material experience using different material properties, namely e-textiles, polystyrene foam, and origami paper. By making the material design decision of specific artefacts a dedicated interest in challenging perceptions of computer science, we were able, through the material manifestation, to challenge taken-for-granted assumptions.

Using the same process for choosing the materiality of the artefact, we also considered the artefact's interactive nature. Again, to challenge taken-for-granted assumptions, it was important that the very interaction also challenge existing perspectives of how people interact with computing technologies. We wanted to open the field of interaction by removing interactions from screens and keyboards and introducing interaction as physical movements, soft buttons, or cloud-based representations. We wanted to demonstrate interaction as single user, as collaborative, and as community interaction. Thus, to the design choices of material we added the choice of interaction. Note that we did not select random materials or interactions for the artefacts but instead explored how the choice of different materialities and interactions would be aligned with the second design principle concerning alternative narratives embedded in the design.

Producing Alternative Narratives

Design artefacts must produce alternative narratives of computer science in the local context. The second principle guides the design process by explicitly producing an alternative narrative opposing the taken-for-granted assumptions. Here considerations about representation of residual populations, invisible voices, and intersectional perspectives are important, and choices should reflect such concerns in the design of the artefact, taking into account the specific context where they are to be enacted. This entails that we as designers consider the *activity*, the *technology*, the *functionality*, the *look and feel* together as one. Emphasizing *alternative* narratives means paying attention to *mainstream* narratives in the context where we work, explicitly identifying the *invisible, often overlooked* aspects of computer science, and bringing these to the center of attention. In this work, we are inspired by the research on reflection, inversion, and defamiliarization by design spearheaded by, among others, Senger, Bell, Blythe, Harrison, and Hertz (Bell et al. 2005; Senger et al. 2005; Hertz 2012; Pierce et al. 2015). Mainstream narratives about computer science are many and multiple – and can be related to the practices that computer scientists engage in, how they work, whom they work with, who they are, what kinds of devices they create, what the material of computer science comprises, what kind of interaction is possible, what kind of situations computer science artefacts are deployed in, and why we have computer science devices and products in the first place.

These diverse questions together form narratives about what computer science entails and are locally situated. Therefore, this FemTech principle guides our design towards choosing one or more of these local mainstream narratives and then identifying what has been de-centered or is invisible in them – and then introducing the identified characteristic as the central focus for the design artefact. In our case, a local mainstream narrative about computer science was that technological products are mainly intangible pieces of software (e.g., algorithms and data). To challenge this narrative, we made visible the materiality of computer science through microcontrollers and physical materials. Further, because we applied a do-it-yourself (DIY) aesthetics to the design, our artefact gave participants an opportunity to see 'into-the-black-box' and to touch the wires, the silicon chip, and physical materials allowing for direct visual access to the mechanics of computer science. The second design principle entails that we, both in the process of creating the artefacts and in the final end artefact, must find ways to manifest the alternative narratives of computer science we are trying to promote. Thus, this reflective design process should consider the *activity*, the *technology*, the *functionality*, the *look and feel* as the design strategy to propose alternative narratives on computer science.

Embedding Storytelling

Design artefacts must embed a story within the design. The third principle relates to the sociomaterial idea that the boundaries of artefacts include their contextual nature – and that this contextual nature is part of what makes the sociomateriality of specific artefacts (Bjørn and Østerlund 2014). The contextual nature of our design artefacts depended on the situation in which we imagined them having a function. The situational approach to the context meant that we in the design process wanted to create stories that would make sense in the context given the participants. We had three ways to design the embedded stories. One approach was to identify stories about hidden minorities in the history on computing, but we also wanted to make the stories relevant for participants in the specific situational context. Concretely, one story was about embedding digital technology in mundane objects to enable uncommon interactions; another was based on tracking computer science topics through tangible interactions. The third focused on using interactive technologies to playfully expose an interesting historic event in computing that allowed us to discuss gender in computing. Each of these stories was linked back to the alternative narrative, the material choices, and interaction features.

The embedded story was important in all our activities, since our artefact alone was not solving any problems, did not resemble any ordinary technologies; thus, we needed the context to explain what it was we had created to make it relevant to that context. The idea of making technology that does not solve a problem but instead explores a situation has received increasing attention in the form of design fiction research (Blythe et al. 2016; Nielsen and Møller 2020; Sicart and Shklovski 2020) and different contemporary approaches to critical design (Disalvo 2012; Bardzell et al. 2014; Menéndez et al. 2017; Rosner et al. 2018a, b; Bjørn and Rosner 2021). We are inspired by these approaches in our work to include a story within the design.

Allowing for Interactive Opportunities

Design artefacts should allow for interactive opportunities that trigger curiosity. The fourth and final design principle focuses on the situation in which the artefact is deployed. Throughout our work is the idea that participants engaging with the artefacts should experience interactive opportunities that trigger their curiosity and allow them to gain a memorable experience of computing. The interactive opportunities are related both to the experience of creating and making the artefacts and to their actual enactment. The interactive opportunity can in some situations be about allowing participants to actually make, build, and program the artefacts; in other situations, participants experience an artefact by interacting with it. We have used both approaches – and it is in the enacting of the design artefacts that the alternative narrative and story emerged together with the participants through their interaction with materials challenging taken-for-granted assumptions.

In deciding how to design an interactive opportunity for participants, it is important to consider how the social design of the event becomes part of the design shaping the context. When we want to promote collaboration, we design the event around collaboration; when we want to promote reflection, we design the event around reflection; and so forth. Thus, it is critically important that when we design a FemTech design artefact, it is not the artefact alone that makes the intervention – it is also the complete social engagement design around the artefact as part of the interactive opportunity (Fig. 4.4).

Fig. 4.4 Four femtech design principles

We have now introduced the design principles produced by our work while guiding it, and we next move on to the two chapters in which we introduce the actual design artefacts created and produced as part of the FemTech research initiative. Chapter 5 focuses on Cyberbear and Cryptosphere – both of which were used to create design workshops for young women prior to their choosing to attend university. Chapter 6 focuses on GRACE, an interactive installation produced for Copenhagen Makers in September 2017, to celebrate the 70 years since Grace Hopper found the first bug in a computer program. The GRACE installation, besides being displayed in Copenhagen, was displayed in Florida, USA, in 2018, and Nice, France, in 2019. For the international installations, we re-designed and re-built the GRACE installation at the specific site, while the original GRACE remains in the makerspace at the Southern campus.