3D PRINTING AS A MEANS FOR PARTICIPATION IN DEVELOPMENTAL SETTINGS – A FIELD STUDY

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ABSTRACT

In this contribution, we detail *Making@Palestine*, a five-week qualitative field study in which we introduced Palestinian refugee children in the West Bank to playful 3D modelling and 3D printing. We analyse 3D printing on a technology as well as an artifact level and identify its potential for participation and empowerment in developmental contexts along such themes as *self-expression* or *physicality & taking things home.* There seems to be considerable potential in 3D printing and other digital fabrication technologies for the empowerment of marginalized population along such themes. However, we also found that the available, consumer-focused 3D printing technologies do not support appropriation as well as they should, preventing especially novice, untrained users from reaching their complete potential. We draw on our fieldwork to outline some of the breaking points in regards to appropriation.

INTRODUCTION

Within our research project "*come_IN"*, we have built a now decade-old, international network of computer clubs as informal learning and integrational spaces in which we work with constructionist projects based on playful tools such as scratch, all based on ICT. However, given the growing impact of the worldwide "Maker" culture as well as more prevalent machines for digital fabrication, in recent times, we also began to work on physical-digital projects such as 3D printing. Two of our come_IN clubs are located in the refugee camps in the West Bank, Palestine. In those clubs, we conducted a five-week field study in which we introduced groups of refugee children between the ages of 8 and 14 to playful approaches to 3D modelling and 3D printing. The field study was grounded in a participatory, qualitative stance on Human Computer Interaction and related methodology such as action research. We were able to uncover many benefits as well as problems with 3D printing in developmental contexts – in this contribution, we focus on aspects of participation and empowerment facilitated and mediated by 3D printing on a *technology* as well as an *artifact* level, grounded in (hopefully) illustrative and thick descriptions of cases from the field. First, however, we will introduce the related work, the rather complex research context as well as our methods:

RELATED WORK

Making (Hatch 2013), the Maker culture, machines for non-professional digital fabrication as well as dedicated spaces such as Fab Labs (Gershenfeld 2005) or Makerspaces have been seeing a boom in recent years which goes for a wide range of fields, ranging from work on complex personal electronic devices (Mellis & Buechley 2012) up to Fab Labs and Making as situated, informal alternatives or additions to traditional educational approaches (Blikstein 2013). There is an overarching discourse about the potential of DIY, Making and the associated machines for digital fabrication regarding socio-economic change towards a more peer-based and individualized world of production (Tanenbaum et al. 2013; Moilanen 2012) – in essence, this is about a certain counter-culture against mass-production and –consumption, instead placing value on aspects such as sharing, teaching and learning, collaboration and, essentially, participation (Hatch 2013).

In regards to Making as well as our work within come_IN, a central notion when talking about education

is *Constructionism* (Papert & Harel 1991), a learning theory which holds that learning actually happens individually through active learning which is best supported by the construction of (individually meaningful) artifacts. ICT is viewed as the best tool to support such constructions. However, when working with complex new ICT such as 3D printing, it is also important to consider how learning processes relating to the machines actually happen (Ludwig, Stickel, Boden, et al. 2014a). The concept of *Appropriation* (Pipek 2005) can help: It describes the sense-making, adoption, adaption as well as changes of user's practices relating to ICT *while actually using it*.

Making and digital fabrication have already shown promise in developmental contexts: there are projects such as DIY prosthetic hands which can be 3D printed in the field for a fraction of the cost of a traditional prosthesis (Krassenstein 2014) and spaces such as Fab Labs seem to attract many relevant ICT4D projects (Mikhak et al. 2002). Arguments have been made to look at Making and especially the related tools and interfaces through a lens of Human Computer interaction in order to facilitate broad participation and to develop better, democratic and more human-centered technologies (Rekowski et al. 2014; Willis & Gross 2011). Hence, Making and digital fabrication can be viewed as the continuation of a stream of research such as (Kafai et al. 2009; Yerousis et al. 2015) which established ICT as a tool to foster participation in developmental settings and especially to bridge the digital divide prevalent in such settings.

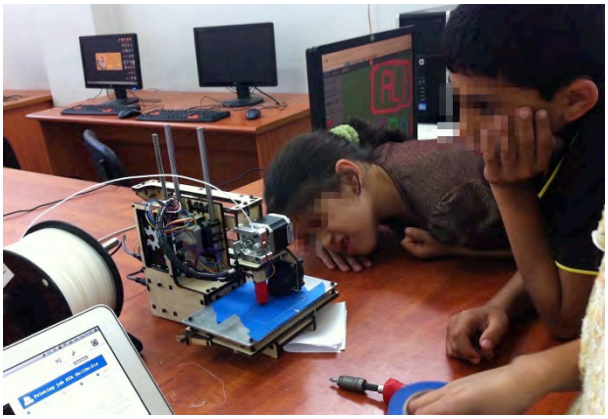

Fig. 1: Come_IN Club

RESEARCH CONTEXT

The Middle East in general and Palestine in particular are war- and conflict-torn areas with a multitude of problems we cannot capture in its entirety here. However, to give a glimpse: Through wars, especially in 1948 and 1967, a significant number of Palestinians fled or were expelled from territories which now belong to Israel. Those waves of refugees led to the establishment of refugee camps (in the West Bank as well as other countries) inhabited by millions of Palestinian refugees – those camps still exist today and face many problems commonly found in such surroundings such as poverty, rickety infrastructure and high population density, but also more unusual ones, mainly the refugee's ambivalent status in their own society: The camps are viewed as symbols for the "*right to return"* (to the areas the people fled from) which leads to no political desire to actually dissolve the camps and integrate their population – however, at the same time, the camps are often viewed as dangerous places and their population as second class, less educated citizens. Most of the refugees live in the camps their whole lives and hardly get out – even services such as (very basic) health care and education in the form of gender-separated and overcrowded schools, run by the UN relief organization UNRWA are located within camp boundaries.

The come_IN (Schubert et al. 2011) network of constructionist computer clubs consists of a network of multiple clubs in Germany, one in the US and two in Palestine, both in/near the city of Ramallah, in the refugee camps of al-Am'ari and Jalazone (see Fig. 1). All come_IN clubs are related to the concepts of the computer club project in the US (Kafai et al. 2009), essentially providing safe and voluntary environments in which people, mainly children, can come together, play, learn and work on individually meaningful projects based on ICT, usually on a weekly basis. Such projects cover a wide variety of areas ranging from storytelling (Weibert & Schubert 2010) up to work with e-textiles (Weibert et al. 2014) Come_IN explicitly targets integrational and developmental settings and is based on a grassroots, bottom-up understanding of education and projects, partnering up with local actors and placing great value on situatedness and context (Aal et al. 2014). The two clubs in Palestine are run together with the local University of Birzeit, which also provides student volunteers as tutors. Of course, the local conflicts are quite prevalent in the clubs – through simple daily life but also through violent experiences such as raids on the camps which can (and do) involve violence and death – such experiences frequently influence club projects (Aal et al. 2014).

METHODS AND DATA

Making itself and especially the research field are quite dynamic and from the start, we knew that we probably would have to work within an unstable socio-technical environment, reacting to necessities and challenges as they came up. Furthermore, trust, participation and personal involvement are highly important in such a sensitive setting (Rohde 2004) which is why we chose Participatory Action Research (McTaggart 1991) as our research framework – essentially, PAR focuses on researching communities utilizing change (through an action, in our case the introduction of 3D printing), the researcher being actively involved in the field, yet at the same time focusing on careful and sound research, e.g. through systematic observation and evolving analysis.

For six sessions (about 12 hours), we moderated the come_IN sessions in the two camps: We introduced the 3D printer by way of a demonstration before

subsequently demonstrating our 3D modelling tool of choice which would be CubeTeam[1], a light-weight, browser-based tool which is inspired by the video game Minecraft in that objects are built from simple cubes and multiple people can build in the same world at the same time. After the brief introduction in which we explained the basic interactions with the tools, our participants (about 20 children between 8 and 14, gender distribution roughly equal) were free to explore and create their own projects with us and local volunteers available for help. The models created by the children could then be printed in situ by way of a 3D printer we brought and left in Palestine (model "Printrbot Simple Maker's Kit", prints with PLA plastic and has a build envelope of 15cm squared). Decisions as to what to make or print were entirely up to the children with us only giving aid on request or obvious need and mainly relating to issues around printability, not the actual theme or content of a 3D model. The children usually worked in groups between 2 and 4 and we observed, took detailed field notes (60 pages), photos and videos. We also talked to the volunteers and the children (hampered through the language barrier).

All data was analyzed using Thematic Analysis or TA (Braun & Clarke 2006) which is related to Grounded Theory in that it aims at identifying themes by way of iterative coding, started quickly *in the field* and *led by the field* (unlike GT, TA explicitly does not include more encompassing theory building which seemed more appropriate for our kind of work). Coding and deeper analysis was done utilizing detailed memos, daily exchange and discussion of memos, codes and notes between the researchers in the field as well as occasional Skype calls with researchers at home in order to ensure inter-coder reliability before finalizing the analysis at home, again, with the participation of researchers not actively involved in the field work.

MAKING AND PARTICIPATION

As we explained in the related work, ICT is viewed as the most powerful tool to facilitate constructionist learning. Our work within come_IN is based on this assumption and, in a nutshell, can confirm it through many successful projects (REF). However, given the specific developmental context of come_IN in Palestine and the introduction of 3D printing, we also saw great potential in ICT, specifically digital fabrication, for empowerment and participation. In the following, we will report on those aspects on two levels: The technology itself as well as the physical artifacts:

TECHNOLOGY LEVEL

First of all, 3D printing, like all Maker-type digital fabrication technologies, aim at enabling essentially everybody to produce things that previously were only accessible through professional manufacturers. In non-developmental settings, such propositions mainly relate to a discourse about mass-production and alternatives in the direction of peer-based production. We could observe a similar effect which emerged especially prominent in the developmental setting. To let our participants speak for themselves:

> *"The children don't have many things to play with […] We now can make things we normally can't […]."* (Wasimah, student volunteer).

> *"We often have problems when we want to import something. They [Israeli customs] don't let things in to Palestine."* (Zahid, local coordinator).

As we can see, there are multiple factors at play: For one, the camp population is very poor and cannot afford many luxury items such as tools and toys for their children. However, this also pertains to essential infrastructure – we were, for example, told of situations where power or water supply would have issues for months at a time due to lack of spare parts and funds to acquire them. The second central factor is the geo-political situation. Palestine is interwoven in a web of conflicts and trade restrictions. This is not the place to explain the latter in detail (more information can be found in REF) – suffice to say that problems with delays, complete restrictions for certain items as well as increased cost due to customs are very common.

Through 3D printing (and other digital fabrication technologies), we see potential to alleviate such problems in a bottom-up fashion. To illustrate this point with a case from our fieldwork:

> *Nahid is a young girl of the age of 9 who was quite curious, motivated, wanted to learn and attended all our sessions. Her favourite animals are butterflies. Prior to our study, she could only draw them on paper and did so quite frequently when she had access to some. Thanks to the 3D printer, she now also can make actual physical butterflies of her very own. Unlike the paper ones, they now have depth and shape – physicality – she would not have been able to achieve with the tools she had access to before. Nahid was very happy with what she could do and poured a lot of remarkably focused work on modelling her butterfly. After printing it out, she happily started to include it in her playing.*

We saw many similar examples during the time we spent in the field. Given the focus of our come_IN club on children, the main usage of the 3D printer revolved around the theme of *self-expression*, i.e. the creation of artifacts with personal meaning, to tell stories or to play with (more on the artifacts below). However, we also saw first seeds of other themes:

> *Aafia, a student volunteer who studies architecture at the University of Birzeit tells us that she is very excited about the 3D printer. She thinks about trying to use it in her studies and wants to talk to the project coordinator to access the printer outside of the club sessions as well.*

[1] www.cubeteam.io

Members of the popular committee also expressed interest in the technology and its potential to manufacture parts they might need for the camp infrastructure such as a water pump but given the fact that we spend only five weeks in the field and focused on our work with children, we cannot report on any empiric results along such themes yet. However, those tentative results serve to illustrate that there is potential in digital fabrication machines to serve marginalized people in developmental contexts along a variety of different themes which all can help scaffold participation and empowerment, such as (playful) *self-expression, learning* (potentially across boundaries) or regarding *functional / infrastructural* lines.

The interest of different people in the 3D printer also serves to illustrate another role of the machines themselves, namely their potential to serve as boundary objects or boundary negotiating objects: Through their flexibility to make many things along different needs or themes but a unifying sense of exploration, empowerment and especially a certain playfulness which seems to be immanent in the machines themselves, they can help to bring together different people or communities of people.

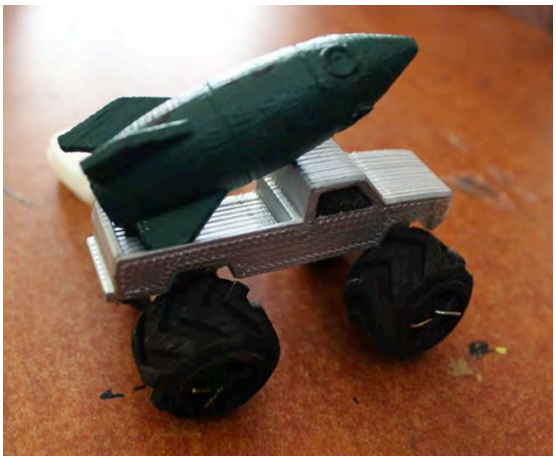

Fig. 2: 3D printed rocket and truck

Fig. 2 shows a rocket on a truck. Both models (rocket and truck) were downloaded from the Internet in collaboration between the children and the volunteers with the former providing ideas what they would like to make and the latter helping them with finding appropriate models. We will talk about the specific models later in detail (see "Artifact Level") but this project serves well to tentatively illustrate the points we made regarding collaboration and boundary spanning:

> *"The children first looked at them [the printed rocket and truck] and they were amazed (smiles). They couldn't believe they were printed on this printer (laughs)[…] We received a lot of comments from the [UNRWA] school teachers in the al-Am'ari school […] They were curious about this 3D printing. It was more about the technology than about the objects […] the teachers even came to the session next week. They wanted to see it how it works and what the children were doing." (Zahid, local coordinator).*

The sense of playfulness, empowerment and amazement of being able to create physical artifacts really seems to inspire curiosity and brings people together – in the developmental context of the refugee camps, the UNRWA schools are overworked and quite bureaucratic which is why a visit and interest by the teachers is rather noteworthy. Based on this interest and the conversations, the local come_IN team even offered to come to the school to demonstrate the printer but due to the aforementioned bureaucracy which includes a lengthy approval process for external projects, this did not happen – which, as a sidenote, relates back to the value of bottom-up approaches to education in developmental contexts. To further elaborate on the potentials of Making and digital fabrication to bring together different communities, we can also draw on our previous research: In Ludwig, Stickel & Pipek 2014b, we found great potential in 3D printers as boundary (negotiating) artifacts, bridging existing community structures or even forming new communities. These results concerned different settings (older Makers in Germany) but we think it is quite likely that the potential of 3D printers to serve as boundary objects is only stronger in developmental settings where there is a common need and wish for empowerment along different themes and different (communities of) people which can be mediated by digital fabrication technologies.

A similar point can be made regarding aspects of community and collaboration which transcend the refugee camp setting: As we indicated in the related work, global collaboration is an important factor for the successes of the Maker movement, especially in ICT4D projects such as the distributed development and manufacturing of DIY prosthesis. For our field work, we are not yet at that level, however, we saw collaboration across camp boundaries, which is remarkable in itself:

> *Gulshan and Nakia live in different refugee camps and usually do not have personal contact. However, by a combination of trial and error, luck as well as constant exploration of CubeTeam's interface, Nakia figured out how to copy a model which Gulshan made in a different virtual world. This led to Nakia remixing Gulshan's Spongebob-inspired 3D model according to her own preferences and fantasies (see* Fig. 3*). Her modifications seemed to be experimental in nature and artistically inverted the figure or attached a frame around it.*

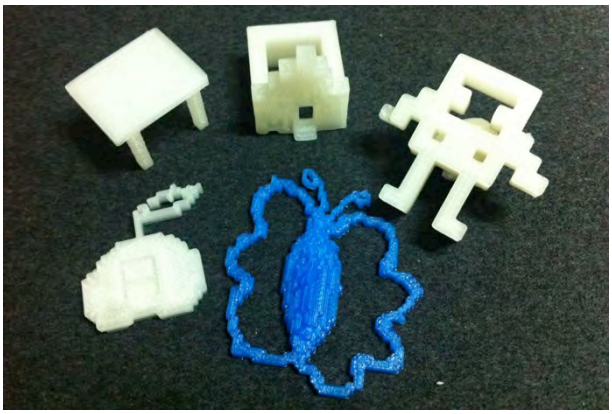

Fig. 3: Various 3D-printed objects modelled by the children

Children in Palestinian refugee camps do not get to leave their camps very often, which is due to poverty as well as the marginalization of refugees in their own society. Hence, the potential for meaningful exchange, collaboration and joint projects across camp boundaries is severely limited, restricting the participation and, ultimately, the empowerment of those children. Through an ecosystem of a collaborative, playful tool for 3D modelling such as CubeTeam and a 3D printer, this changed. Obviously, such collaboration was and is also possible through completely virtual means (such as Scratch-programming projects). However, the possibility to virtually collaborate and then have those virtual creations take physical shape wherever desired seems more potent than non-tangible collaboration. To let Aafia make the point:

> *"They [the children] can now work together and really see and really **touch** the things. It is amazing!"*

Based on our observations, we can only confirm the importance and the feeling of empowerment of being able to touch things of one's own (co-)creation which is ultimately enabled through digital fabrication machines and their ecosystem. This in turn is a fitting transition to talk about the actual physical artifacts and their relation to aspects such as change and participation:

ARTIFACT LEVEL

Obviously, the actual artifacts created by the use of 3D printing are also quite relevant when talking about Making and digital fabrication and participatory aspects in developmental contexts. We will focus on two main themes we found to be central: *Self-Expression* (aka: *Making voices heard)* and *Physicality & Taking Things Home:*

One of the most powerful examples for aspects of self-expression can be found in the rocket truck we already introduced (see Fig. 2). To give some more context:

> *"One team, they wanted to print a race car, another wanted to print a truck and a third team wanted to print this lunar rocket […] [after the models were printed] one team came up with the idea to colour them […] and they realized that when they color it in a certain way, they can mask that it is a lunar rocket and they can say that it is a rocket that can be used in Gaza […] They talked about it, they played with it, they even named the rocket […] I'm not sure if they chose correctly, but they put an "M75" on the rocket because they know this particular "brand". They played with it and, you know, we were a bit hesitant with the children to continue to talk about this topic because we didn't know where it would lead to […]" (Zahid, local coordinator).*

Through engaging with the actual, printed artifacts and thinking about colouring them (the base colour was an off-white tone), the children actually came up with the idea to combine models which originally had separate meaning into something relating to their dire straits - the artifact, in this case, is intricately linked to the violence in the area – as Zahid put it:

"*They are usually moved by emotions and we have a local channel, a Palestinian local channel that has been broadcasting live reports from Gaza and showing pictures of children being killed, showing pictures of homes, so this is what children in the refugee camps were exposed to".*

Hence, the artifact provided an outlet as well as an object for discussion – uncomfortable and difficult discussions but obviously topics highly relevant to the children. There were also more peaceful examples relating to self-expression such as Nahid, the girl we already introduced and who likes butterflies so much or the house Rabi, a girl of 10 made and individualized with inscriptions as a *"new house for her family"* (see Fig. 4) – this wish for a new home, however, also relates back to the living conditions in the refugee camps which, as we explained in the research settings, are cramped, rickety and plagued by failing infrastructure. Rabi, understandably, expressed – and, through the model, showed – her desire to live elsewhere, in a bigger home owned by and made for her and her family.

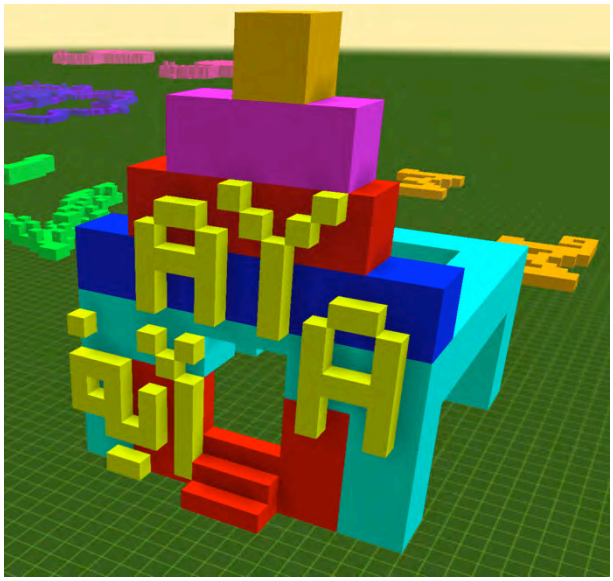

Fig. 4: A new home...

The second central dimension we would like to report on relates to the *Physicality* inherent in 3D printing. We already talked about such aspects on a machine level but the fact that things can be made relatively quickly, cheaply and easily has a very central implication for participation in developmental settings: The ability to *Take Things Home.* Zahid recapitulates months after our visit (and after supervising many more 3D printing projects on his own):

> *"all the creations, even when [German researchers] were here, they all wanted to take them home. They were really proud of it and wanted to show them to their parents and maybe to their friends at school."*

We noted similar effects during our field study:

> *A group of three boys, for example, figured out that they could model eyelets attached to the already finished models of their initials in order to make their creations wearable. This discovery happened in both camps we worked independently and each time, it spread quickly by word of mouth as well as over-the-shoulder learning. The children expressed great satisfaction regarding being able to carry around their creations on their bodies and some of them showed off their brand-new bracelets or necklaces fashioned from string and the 3D prints in the next sessions. Nahid, the girl who likes butterflies was especially proud, approached us and showed a bracelet with her initials while smiling broadly.*

The relevance of this effect for participation in developmental contexts should not be underestimated: Based on our own experiences with purely digital projects (Scratch, basic HTML, etc.), we often noted that it was difficult for the children to actually talk about their projects and their accomplishments outside of the clubs – simply because such conversations had to be quite abstract: Showing a Scratch project to parents at home is impossible if there is no computer and no Internet available. Showing a physical artifact, on the other hand, is quite possible and proved beneficial in that it enabled deeper conversations between the children and their friends, parents or even teachers. It did not stop at conversations – as we can see in the bracelet example, the physicality also enabled actual collaboration and engagement with the artifact outside the clubs. Wearability and other individualizations (such as name or inscriptions of initials) seemed to relate to this aspect. However, the motivation to take things home, to show and tell, did not only relate to the models the children made just for themselves but also the collaborative creations like the rocket truck:

> *"Everyone of the children wanted to take it [the rocket truck] home with them and we could not print duplicates for all the children, so we told them that each child can take it home for one week and then bring it back to the clubhouse and then another child would take it. But the student volunteers also wanted to take it home with them, so we also gave them a chance as well." (Zahid, local coordinator)*

DISCUSSION AND OUTLOOK

We were able to identify potential for participation and empowerment in digital fabrication – in this case, 3D printing. This potential can be categorized along the lines of the technology itself as well as the physical artifacts:

On a technology level, the 3D printer acts as an enabler for the creation of objects previously too expensive or simply not available. This represents a significant chance for poor and marginalized settings in general and, specifically, settings where external (trade) restrictions are in place – such as in the Palestinian setting we were working in. Bottom-up, constructionist "Maker" settings such as come_IN with a focus on education and integration or the world-wide Fab Lab movement with its less specific foci always aim at empowerment through ICT but the value behind those aims and a grassroots-inspired approach, again, really shine in marginalized settings. A key aspect here, however, is a socio-technical view on ICT: Human-centered, collaborative approaches to 3D modelling and 3D printing have proven to be quite motivational, especially for beginners. This aspect is reinforced by the playfulness and the sense of joy immanent in technologies that empower people to give *their* creations physical form. We saw quite similar effects in studies with older Makers in very different, western settings (Ludwig, Stickel, Boden, et al. 2014a). Taken together, playfulness, collaboration and the sense of empowerment seem to work really well to imbue Maker technologies such as 3D printing with the quality of boundary objects: People come together, have conversations, share ideas and start projects such as the rocket truck we reported on. Such (intrinsic) motivation to engage in projects is far from common in depressing settings such as the refugee camps we worked with where unemployment and – after what are now multiple generations of marginalization – lack of motivation is frequent (Aal et al. 2014), while the collaborative aspects are beneficial to connect people from different areas (such as our two refugee camps) which might otherwise hardly ever collaborate given socio-economic hardship hampering their movement.

One of the key aspects why we deem digital fabrication to be so powerful for developmental contexts is the fact that the machines do not just stand for themselves but produce artifacts which can be *taken home*. Unlike with other ICT such as traditional computers, people – in our case, the children – can touch, take, carry, remix and modify their creations in the physical world. This adds to the sense of empowerment but most importantly, it lets the creators tell the stories behind their artifacts in many different situations without access to ICT itself which is crucial in developmental settings. This makes for great, situated potential for meaningful conversations as well as collaborations – as we saw

when children suddenly engaged in joint work with their parents on their 3D printed pendants at home. The situated availability together with the tangibility and relative simplicity of the 3D printed objects seemed to do break boundaries such as the scepticism of many older parents regarding computers which they often do not understand (Aal et al. 2014).

Of course, we have to acknowledge the fact that the creations we saw come into the physical world were all relatively simple and centered around playful themes of personal self-expression – this is valuable in itself but not sufficient for lasting socio-economic change. However, we saw tentative roots of other projects such as more complex approaches taken by the students and given the interest of officials from the camp committees, we hope to see the empowering aspects of digital fabrication in the refugee camps spread wider in the future. To achieve this, 3D printing in itself probably is not sufficient either. The Fab Lab idea (Gershenfeld 2005) which focuses on grassroots-spaces for digital fabrication with a portfolio of machines which can produce (almost) anything might certainly be more sensible to foster bottom-up empowerment and production in the long term. The caveat here is – for the most part – cost: 3D printing has drastically decreased in cost and increased in availability while other Fab Lab technologies such as laser cutting or CNC milling are still more expensive. However, there are more and more projects such as the Resha laser cutter[2], the Lasersaur[3] or Open Source CNC mills[4] which will, in time, bring those technologies to a more affordable and available level as well, potentially enabling a more encompassing web of bottom-up empowerment in developmental contexts through digital fabrication (Mikhak et al. 2002).

Another caveat we need to discuss is the fact that, for now, certain aspects of the digital fabrication process are more difficult and hard to appropriate than others. Creating a 3D model – the basis of all digital fabrication – is surprisingly easy, the learning curve works well and there is already a certain structure to foster appropriation like a variety of collaborative tools such as CubeTeam which we used. However, when it comes to making a physical object from the model, the path usually is thornier: There is usually no integration between the 3D modelling tool and the 3D printer; the software users need to print is usually complex to calibrate and operate; there are many parameters to consider; and the 3D printers itself have to be calibrated, cared for and handled properly as well. Furthermore, they can be dangerous through hot or moving parts and an open construction. If we think about more advanced digital fabrication such as CNC milling, things only get more complex and hard. However, we believe that most of these issues are solvable through more integration between soft- and hardware and carefully designed mechanisms to support appropriation such as feedback loops, simulations, etc. regarding printing directly in the 3D modelling tool, accompanied by sensors and feedback systems integrated into the digital fabrication technologies itself. We talk about such issues, to an extent, in (Ludwig, Stickel, Boden, et al. 2014a) and will elaborate on them with a focus on the project in Palestine in (Stickel et al. n.d.).

For our future work, we are currently setting up a similar study as we did in Palestine in one of our German come_IN clubs – however, we explicitly plan to facilitate collaboration between the Palestinian and the German children – we are very curious to see how the aspects of playfulness, collaboration and especially the physicality and the self-expression through artifacts pan out in such an international setting with significant cultural and language barriers. In a more long-term view, we are also thinking about how to bring other, more complex digital fabrication technologies into the refugee camps and how to facilitate their appropriation there. Furthermore, we are working on approaches to integrate bottom-up, constructionist project work and learning into more formalized education: Given the fact that most education (in developmental as well as other settings) happens in institutions such as schools, we think that it might be sensible to bring those institutionalized forms of learning together with the sense of empowerment and participation as well as the situated learning effects (which in turn again foster empowerment) enabled through digital fabrication.

To sum up: We believe there is great and immediate potential in digital fabrication for the empowerment of marginalized population along more playful themes of self-expression. In a more long-term view, we see this as a potential road towards a more encompassing participation of such populations regarding the production of physical goods in a grassroots and peer-based approach – given carefully and better designed technologies for digital fabrication - from an engineering as well as an HCI point of view with foci on affordability and scaffolding as well as supporting appropriation, respectively.

We would like to thank the come_IN team in Palestine for their hospitality, their participation in the project and their great motivation for change in their hard and often dangerous surroundings.

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