Deconstructing Sociotechnical Identity in Maker Cultures

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ABSTRACT

In this paper we argue that Makers engage in various degrees of sociotechnical identity formation. We explore the role of gender in maker identity formation and how the masculine characteristics of maker spaces create challenges for feminine identity construction and expression. Our ethnographic study of German computer clubs indicated that children as Makers synthesize gender and technical identities within the context of STEAM skill building activities.

CCS CONCEPTS

• **Human-centered computing → Human computer interaction (HCI); Ethnographic studies; User centered design; collaborative content creation.**

KEYWORDS

Gender, making, Making; maker movement; DIY; innovation; German; identity, HCI.

1 INTRODUCTION

Makers engage in various degrees of sociotechnical identity formation; these different gradations, including gender, are potentially hidden and obscured by masculinist constructions of gender and technology relations, particularly within conventional maker spaces [24.][57.]. Often technological knowledge is perceived and understood as a masculine trait [24.][57.]. This DIY (do it yourself) ethos which focuses on maker's ability of to enact and embody "anti-mass production" values that encompass a "non-luddite critique of technology" [3.], p 4023] making

sociotechnical identity construction key to understanding maker culture. Furthermore, some scholars in HCI have proposed that maker culture values promote creative engagements with tools and artifacts, and thereby create opportunities for multiple and playful sociotechnical identities to emerge as a result of these human and technology interactions [30.] [54.] [56.][57.]. However, feminist HCI scholars such as Toupin [57.] and Fox et al. [25] actually continue to construct feminine sociotechnical gender identities as nontechnical; these perceptions are directly linked to binary and heteronormative gender categories within traditional computing cultures [17.][22.][35.][39.][44.]. This is problematic as maker cultures have the potential for providing an alternate route for women into STEAM fields (Science, Technology, Engineering, Arts and Math), but this cannot happen if technological competence is constructed solely as a masculinist trait.

Gender is an explicit dimension of maker culture; as makers create sociotechnical identities that include the opportunities for these practitioners to demonstrate technical abilities that assist them in sharing "their craft and subsequent creative satisfaction" [3.], it is possible that feminine sociotechnical identities still require additional investigation within these maker spaces to become visible and valued, by both HCI scholars and the maker communities that support the construction of these identities. While researchers have discussed gender issues in maker culture [24.][57.], and still others have focused on how individual makers might create their sociotechnical identities [57.]. HCI scholars have not yet discussed in depth how an individual maker's gender and technical identity are co-constructed in concert with one another. Here we propose to do so, extending the findings of an earlier qualitative study of children's maker spaces and making practices [63.]. Our earlier findings included some discussion of gender, but not a detailed discussion of how makers construct their own gendered and technical identities. We will analyze the data using Rode and Poole's model of the co-construction of gender and technical identity [48.], as it is an applicable frame that allows us to view the varied nuances of how gender and technical

identity are co constructed at the locus of interaction between makers and technology.

We hope to bridge the gap between literatures that discuss gender identity [24.][57.] and those that examine the process of sociotechnical individuation in maker spaces [57.]. Our qualitative study of children's making practices allows us to understand how playful and nonlinear engagements with technology, or bricolage (learning by doing), is a crucial dimension of how gender and technical ability intersectionality influence one another. We analyze children's maker spaces via Rode and Poole's model [48.], to display particularly how gender impacts sociotechnical identity formation at individual, structural, and symbolic levels, and to construct an understanding of gender and technical ability as interrelated concepts, that occur at the loci of interaction between makers and artefacts through the practice of bricolage [21.] [42.] [51.]. We hope to unpack the nuances of individual, structural and symbolic components of sociotechnical identity construction as levels of engagement with technology that by extension permit a more expansive dialogue with regard to addressing diversity issues in maker culture. This is especially important given how STEAM can support diversity in computing cultures and the role of maker culture of exploring how STEAM skills in turn support understandings of how gender and technical ability are linked.

2 RELATED WORKS

Next, we will discuss some of the concepts in the background literature on which our argument relies. First, we will overview the model we hope to extend as the contribution of this paper. Then we will briefly then discuss the small body of literature bridging gender and maker culture.

2.1 Model of the Co-Construction of Gender and Technical Identity

Often when discussing gender or technological identity construction we lack the nuanced vocabulary for discussion. In Rode's ethnography [44.], she constructed grounded theory using queer and gender theory to lay out to the various factors that play a role in gender and technical identity as well as, their influences and tensions. This theory was a textual model of Co-Construction of Gender and Technical Identity.

Building on this this theory Rode and Poole [48.] created a visualization of Rode's theoretical model [44.] (See Figure 1.). Here they discussed the model in light of Rode's initial data set, and showed it also applied to Poole's data set. For basis of this paper we are discussing the theoretical aspects of the model that were peer reviewed as part of Rode's dissertation, borrowing only the visualization from Rode and Poole's unpublished work.

Gender and technical identity in maker culture are complex, and we believe the discussion, like discussion of gender in domestic technology use, is similarly hampered by inadequate vocabulary to describe the interactions occurring between gender and identity construction. Understanding identity construction is vital if we wish to recruit people with more diverse gender identities into STEM, as masculine technology culture is known to come into conflict with feminine gender construction [17.][22.], [58.]

We chose to study maker spaces as they are vital venue for recruiting people into STEM (Science, Technology Engineering and Science) by giving them exposure to new technology. We selected a children's maker spaces in particular as they allowed us to explore gender and technology identity construction in a formative stage.

Thus, in this paper we wish to apply and extend Rode and Poole's model of the Co-Construction of Gender and Technical Identity to the maker space. We will show the model is appropriate for discussing makerspaces, and further by using it we will be able to present our findings regarding children's makerspace use. The model will allow us to show how individual makers, have unique ways of engaging with and presenting gender and their experiences and attitudes towards technology. We call this gender and technical identity co-construction. This identity construction occurs on an individual level in response to social pressures. Next, we will unpack the terminology of gender and technical identity on which our argument is based.

2.1.1 Technical Identity

Individual technical identity in this model is comprised of three aspects.

1.   Technical ability is people's factual knowledge and ability to do a particular task [44.]. For instance, a user knows how to construct a circuit with a LilyPad and program it to mix color in response to a light sensor.

2.   Self-efficacy is one's confidence in one's abilities [9.][48.] One might have the technical skills to program that circuit, but they might lack the confidence to think they are going to succeed.

3.   Finally, presentation of agency is whether an individual conveys that confidence when interacting with others [48.] this is based on Ortner's theories around agency [40.]. A maker might possess the skills and have self-efficacy, but choose for one reason or another to act like they do not know how to do something. For instance, Rode documented [44.] women down playing their abilities to encourage demonstrations of chivalry [19.]. In a maker context someone might act as if they do not have agency, because they want the attention of someone helping them. Of course, we acknowledge that other reasons that do not rely on norms binary gender roles may also be a motivation for the presentation of agency.

In order to discuss a maker's presentation of her technical identity we have to understand how each of these three aspects occur in concert with one another. In this paper we will show here how each of these aspects of technical ability readily apply to maker culture, as well as maker identity.

2.1.2 Gender Identity

Our discussion of makerspaces requires us to differentiate the terms sex and gender, as well as different types of gender. Sex refers to one's physical characteristics, whereas individual gender refers to one's own gender identity [26.]. Individual gender need not be binary and may be different than one's sex.

Individual gender and technical identity are co-constructed in response to one another, but also in response to social pressures.

Here two other aspects of gender become relevant--structural and symbolic gender [26.]. Structural gender refers to how gender divisions are reflected in society, be they binary heteronormative ones, or more gender diverse ones. Second, symbolic gender refers to the gender inscribed on artifacts which are often based upon structural gender. Structural and symbolic gender are relevant for girls in maker spaces who wish to construct a feminine and technical gender identity. They have to reconcile their identity construction with structural gender roles in society [58.], as well as the symbolic gender of their tools.

As we refer back to the LilyPad example earlier in this paper, girls engaging in maker culture encounter structural gender roles that imply STEM is more suitable for men than women. For instance, the recent Barbie book *I can be a Computer Engineer* [41.] includes the following passage: "I'm only creating the design ideas," Barbie says, laughing. "I'll need Steven and Brian's help to turn it into a real game!" Here Barbie is reaffirming structural gender norms that girls cannot program without a boy's help. This is a real social pressure that impacts children in maker spaces. To counter this perception, the activist designer of the Lilypad attempted to engage with the symbolic gender of the circuit board for their e-textile system, in that instead of the typical green rectangular circuit board a round purple circuit board was used to attract girls [14.]. Additionally, structural gender played a role as Buechley hoped sewing, a feminine craft skill, would draw more young girls into programming [14.].

In this way the model affords a more nuanced discussion of the types of gender and identity construction going on in maker spaces. In this paper we will present our ethnographic findings of a children's maker space, and use this model to will discuss how gender and technical identity are vital to understand a maker's identity. In doing so we will argue maker identity must be discussed with a gendered dimension.

2.2   Bricolage and Maker Culture

Having now established our terminology, it is critical to establish that this identity construction occurs in a specific cultural context of bricolage and marker culture [11.]. Levi-Strauss [32.] identified one of the tenets of maker culture, bricolage, (or learning by doing) as a cultural phenomenon with both nonwestern antecedents and of a lesser composition than industrialized engineering culture. However, Turkle's assertion that Levi-Strauss' notion of bricolage did not include "a way of combining and recombining a closed set of materials to come up with new ideas" [59.] supports Derrida's earlier critique of Levi-Strauss of bricolage as a powerful disruptor of epistemic binaries that promote scientific ideation through innovation to establish new ways of knowing [20.]. Contemporary scholarly discussions in HCI support the perspective that maker culture actually promotes the idea that makers and bricoleurs (makers that engage in nonlinear learning and creative tinkering) generate "their creations ultimately for humans first and efficiency after, which is why they watch how people resonate with their creations, discussing recently catalyzing events contagiously and sharing immediately, even/especially with kinks still in the design. This

leads to viral reproduction of ideas and creations where mutation, not replication, is the normal expectation" [49.]. This has been examined from the perspective of STEAM (Science, Technology, Engineering, Arts, and Mathematics) educational principles explored by numerous scholars [1.] [28.] [63.] particularly with regards to children's development of technical self-efficacy through playful engagements with technology, and how these interventions are linked to gendered sociotechnical identity formation. As Turkle has observed that "discoveries are made in a concrete, ad hoc fashion" and only later recast into "canonically accepted formalisms" [60.], we can understand that children's ability to creatively interact with technology through leisurely activities can in fact also be used to examine how restrictive paradigms surrounding binary gender identities might be with regard to technological self-efficacy and identity. The children's approach to technology, in terms of the STEAM philosophy, which includes the creative and exploratory elements valued by the maker ethos, support the notion that maker culture can in fact expand beyond Levi-Strauss' view of bricolage as a restrictive, lesser form of technological human understanding [23.][62.] and instead promote an emancipatory context between technology and identity formation in which diversity can flourish in computing cultures [15.].

2.3   Gender in Maker Culture

It is critical to establish that this bricolage, a term first introduced to HCI by Blackwell [11.], occurs in a highly gendered context. Feminist scholars outside of HCI, such as Butler [16.], have argued that binary gender roles are both problematic and restrictive, as masculinist hierarchies of gender insist upon heteronormative dimensions that ultimately refuse to acknowledge "whatever biological intractability sex appears to have, gender is culturally constructed: hence, gender is neither the causal result of sex nor as seemingly fixed as sex" [16.]. She further elaborates on the idea that binary gender categories are not mapped directly and naturally onto biologically sexed bodies as equivalent and normative; she suggests that "when the constructed status of gender is theorized as radically independent of sex" the result is that "man and masculine might just as easily signify a female body as a male one, and woman and feminine a male body as easily as a female one" [16.]. Thus, sex and gender are determined independently of one another [26.]. Varied and non-binary constructions of gender identity formation can be construed as separate from biological sex taxonomies [12.]; this in turn creates a space for normally obscured gender sociotechnical identities to manifest and become visible. Technology as masculine culture conventionally insists upon gendered binaries that in fact privilege both biologically male and socially masculine identities [16.]; these binaries inherently support heteronormative restrictions that ignore a diverse spectrum of gendered maker personae.

Furthermore, since technological artifacts in their production and use mediate sociotechnical identity formation, gender performances around technology become in the scholar Barad's terms, "practices/doings/actions" [4.] with material and tangible

results. These material impacts have been discovered through ethnographic studies of feminist maker spaces. For instance, Touphin's [57.] work featured feminist and queer identified women generating maker values that allowed for spaces where diversity became possible and open. Fox et al. [24.] researched maker spaces that included women who particularly described themselves as mothers, and queer women; these are two subcategories of women that have often been alienated from computing cultures [24.] [48.] 64], They are just two examples of a broad range of feminine sociotechnical identities that maker culture can potentially support.

3 METHOD

This paper is an extension of the analysis of earlier fieldwork [63.] with three children's maker spaces in Germany. These groups were weekly and lasted for 90 minutes a week for five weeks. We worked with both girls and boys aged 8-12, around the age girls often lose interest in computing [34.]. These maker spaces called Come_in, have been going on for 4-7 years on average. In addition to creating a fun environment to learn skills, the key goal of these spaces was to encourage children from a mixture of German and immigrant backgrounds into a cohesive community.

Our mixed gender sample was essential to our understanding of maker identity and user agency in children, with particular attention paid to feminine skill building, as these are often invisible and invalidated in traditional learning spaces and computing surroundings. The informal and flexible nature of the activities supported creativity and peer collaboration; these have been identified as components which foster the development of both user agency and computational self-efficacy [1.] , [28.] [63.]. The children soon applied creativity and collaboration as two major tools of gender presentation and self-efficacy.

We conducted an ethnographic study that incorporated participatory observation [63.]. Participatory observation within HCI is one way in which feminist scholars such as Ann Light have acknowledged we can support a "nonessentialist position on the formation of identity" [33.], p. 437] in order to discover both agency and identity in tandem. Furthermore, we designed interventions for our mixed ethnic and gender sample of children to better understand how we might "create a space that is flexible enough to keep the discussion open as to who we might turn out to be" [38, p. 437] Participatory observation is a conventionally applied anthropological ethnographic method within HCI that is both reflexive and qualitative [25.] [45.] [63.].

3.1 Our Children's Maker Spaces

We focus on our work with three children's maker spaces in Germany: A, B and C. These spaces represent a range of socioeconomic and ethnic groups. Participation is free of charge, and is voluntary, though the Maker Space A represents one of a set of subject choices for the students. A teacher from each school and tutors from the research team guided maker space activities at each of the maker spaces.

Maker Space A is located in a grammar school in one of the larger cities in the Rhineland area. The neighborhood includes people

from about 120 countries; every second person in this neighborhood is of an immigrant background. The unemployment rate in this area is above the city's median rate of 8%; goodly portions of those who are unemployed are also of foreign descent. Also, the average family income in this neighborhood is less than half the amount of normal family income in other parts of the city. Maker Space A was founded in 2009. Most of the 14 children in the maker space had immigrant backgrounds. Many are originally from Turkey, Lebanon, Afghanistan, and Russia. Six girls and eight boys, ages 11 to 12, participated in our study.

Maker Space B is located in a primary school in one of the large cities in the Ruhr Area. It is based in a neighborhood that stands out in the city not only because of its high population density, large number of families, and comparatively young ages of its inhabitants, and 57.7% of the population has immigrant backgrounds. There are also high unemployment rates, low wages, and obstacles that make access to higher education difficult. Neighborhood inhabitants, a local non-profit organization and neighborhood managers brought this maker space to life in 2009. The immigrant backgrounds present in the space's community mirror the diversity of the surrounding neighborhood, with children and adults stemming from Turkey, Albania, Macedonia, Tunisia and Morocco. Five girls and five boys, ages 8 to 10 participated in our study.

Maker Space C is located in an elementary school in a mid-sized town in the Siegerland area. In 2005, 13.4% of the inhabitants of the surrounding neighborhood had immigrant backgrounds. This number has increased to about 17% in the last years. Maker Space C was founded in 2006. The participants resemble the cultural diversity of its neighborhood. Half of these participants were German, and the rest were from Turkish or from Eastern and Southern Europe. Two boys and seven girls, ages 8-10, took part in our study.

3.2 Analysis

We analyzed our data using the grounded theory method using feminist theory as the theoretical frame [46.] [52.]. In our earlier paper we discuss how our progression from open codes to selective coding created a key narrative about gendered making [63.]. While in our earlier paper we alluded to it extending Rode and Poole's theory of gender and technical identity (here we explicitly show how our data fits and extends this model) [48.].

3.3. Children's Maker Space Activities

We helped the children in all three groups learn about e-textiles with training activity (for details see [63.]). Next, the children in each of the three maker spaces did different projects. These projects built on the training and were equivalent in terms of task and scope. They were tailored to the members' respective expertise, interests and ages.

Figure 1. Flexible switch, battery holder, LED and conductible thread were used for the LilyPad Freestyle activity. (Photo by Anne Weibert)

Club A's activity was freestyle, so after the introductory session, the children were asked to develop project ideas involving circuits and programming. Two groups emerged; one was enthusiastic about programming music with sensors and the other created figures from fabric each with a sewn-in circuit and flexible switch enabling them to light up (See Figure 1).

Figure 2. The circuit board for the Bunny Bright project. (Image source: https://www.sparkfun.com/products/retired/10708)

Club B used the Bunny Bright electronics kit for children from the age of 5 and up is designed to teach basic electrical knowledge [50.]. Following the instructions of an adult, the children soldered the LED, a reed switch, a resistor and a battery holder onto a circuit board (See Figure 2). After completing the board, the switch could be activated by a magnet, and the LED lights up. The circuit board was sewn into a stuffed animal; in the case of our project this was a stuffed rabbit containing the board with a carrot housing the magnet. When the carrot was touched to the rabbit's

mouth, its belly lit up to show it was happy. Some children elected to create alternate forms.

Figure 3. Project results from Maker Space B. (Photo by Konstantin Aal)

Club C used electronic-textiles with LilyPad sewn electronic components (See Figure 3). The fabric is still flexible components were hidden in the fabric and invisible to the eye. In this project the children create a circuit with a battery holder, conductive thread and LEDs on a piece of fabric. Once the electric circuit is established and the battery inserted, the LEDs light in the eye lit up when squeezed.

4 FINDINGS

We will discuss our findings in light of the model. The three aspects of technical identity, technical ability, self-efficacy and presentation of agency were all relevant. Technical ability included whether students knew how to program, sew, draw etc. All children were taught to draw basic shapes, and coming up with project ideas was certainly within students' abilities. Various students asserted they could not draw or could not sew, yet later many students demonstrated such abilities. The question is whether they lacked the confidence they were able to do this correctly (self-efficacy), or if they were engaged in a presentation of agency and posturing that they could not for some social reason. Consider the boy, who, on considering whether to join the wholly female soft circuit group said, "I can't draw. I can't sew. I'm not going there. No way!". It is difficult for us to know what the true motivation was for this outburst. Did he actually not have these skills, and a lack of technical ability? Did he lack confidence, and self-efficacy? Or was he presenting himself as less capable than he was? This could be because he wanted to set expectations low so he did not disappoint, or perhaps did not want to appear unmasculine. Perhaps preserving his masculine identity was more important to him than demonstrating his capability to do the task. Only careful ethnographic work, over a longer period of time than the study here includes, would fully explain these issues. We endeavor to investigate this more fully in our future work. Next, in this paper we will discuss gender identity by discussing the

three types of gender next, as we do so tie these issues back to technical identity as appropriate.

4.1 Structural Gender

Structural Gender focuses on gender roles in society. In our maker spaces, while maker skills themselves can be applied to a wide array of problem domains, and yet we see individuals gravitate to choices constrained by structural gender. For instance, in Maker Space A we saw student's project selection be based on gender. Initially, all of the girls gravitated to making soft-circuit stuffed animals, which used conductive fabric to create a circuit such that when they were squeezed they lit up. The boys elected to create computer music, task that required programming and no sewing or drawing. As one boy said, "I can't draw. I can't sew. I'm not going there. No way!" The boys did not have experience playing or reading music, so this was not a factor in their choice. While the gendering of skills required, and a desire to self-group by gender are likely also factors; the domains of stuffed animal making versus music composition, as the activities themselves have a gendered dimension. Similarly, another group while doing the training session had organized itself in same sex teams. Here a group of girls had difficulty getting the light sensor to control the LED, and sought help from the tutor. While the boys had been working separately, when they too encountered this problem the girls and boys began collaborating. Thus, while making is often organized around structural gender initially, we view the possibilities for renegotiating these binaries as a boon for maker culture.

Structural gender is especially relevant to maker culture given its open ethic [54.][56.] which espouses equality, despite this patterns of marginalization based on biological gender are apparent in the literature [24.] [57.]. The literature suggests women are in the minority of maker space participants [24.] and women feeling marginalized in the community [57.]. Our data from this study as well as our last three years of e-textiles research supports this. All of this suggests structural gender is a barrier for women in maker spaces. Thus, this needs to be addressed to achieve gender equity for getting women both into maker spaces and in STEAM. Policies and research aimed at addressing these disparities has focused on changing the culture, by creating women's only spaces or creating policies for behavior [25, 65]. While we find these efforts, laudable there is a sociotechnical dimension here, just as Cockburn and Wacjman argue which also need to be considered [17.][62.]. Findings by Fox et al and Toupin show that LGBT perspectives in maker cultures have been marginalized [24.] [57.]. and by extension gender roles are largely binary. Toombs et al's work for instance ethnographically studied makers' constructions of tools to aid in their crafts, but despite their open sampling method did not include any female tool makers [56.]. Given their careful and open-ended methodology, this suggests there just were not any women who did this, which reifies the idea that maker spaces are predominantly masculinist environments, and that making is a masculine pursuit [24.] [57.]. We need to understand ways in which women can construct technical identities that run counter to normative structural gender that assumes women are not

technical. Women are construed and constructed as non-technical and passive users within conventional computing cultures [23.] [62.]. Tannenbaum et al [53.] among others have observed the democratic potential of the maker culture ethos. Our data showed variant gendered patterns in skill building and activities with regards to the problem domains selection which we will discuss next.

4.2 Symbolic Gender

While structural gender focuses on social conventions, symbolic gender focuses on the gender we associate with objects including tools. Making requires a range of skills from coding to engineering, from soldering to sewing, from drawing to carpentry. These skills are enmeshed in attitudes toward about appropriate structural gender, and the tools themselves have strong symbolic gender. Repeatedly we see discussion of some 'hard' skills being gendered as masculine, whereas other 'soft' skills are gendered as feminine [18.] [61.] [62.]. Faulkner [22.] and Turkle and Papert [60.] discuss how programming and other engineering skills are considered traditionally masculine. Our fieldwork shows how skill building expands beyond binary gendered categories. For example, while some of our tasks required a mixture of traditionally femininely and masculinely gendered skills [63.], the gendering of skills has the potential to act as a barrier for students who conform to binary gender identities.

At the same time supporting girls who might have more traditional individual gender, brings with it the possibility of supporting STEAM skills. In Maker Space C where aesthetics proved a strong motivation for the girls:

Girl 1 to Girl 2: "Make it be blue again!" (She takes a picture of the bright-lit blue LED.)

Girl 2 takes the LED and LilyPad: "Now it's me – I want the pink!"

This focus on aesthetics was not purely cosmetic in that affected girls' understandings of circuitry; the skill building in this activity combined electrical engineering, computational thinking, and aesthetic choices. The girls in this group were concerned with the stitched circuit looking good, and using the stitching to support the overall design. For instance, a pair of girls wanted their stiches incorporated in a flower and a pig design:

Girl 1, to a tutor: "I could go like this. But it's ugly!"

Girl 2: "Same here! I don't want this in my picture."

The girls were able to focus on aesthetics by synthesizing their creative choices with a sophisticated understanding of circuitry. They had to ensure their negative and positive traces did not touch, and in some cases considered sophisticated insulation to support a design, or had to relay the circuit out. This resulted in higher levels of mastery. The students who were not focused on aesthetics, largely the boys, did not pay similar attention to constructing circuit. Therefore, the symbolic gendering of skills impacted learning.

Once makers have developed skills they must choose which to use in a given situation. One can connect an e-textile circuit using a range of skills—sewing, painting or wiring are all possibilities. One could use conductive thread to connect two components of a circuit using stiches on material, one could use conductive paint

to connect by painting a line between components on a planer surface, and alternatively an alligator clip or wire can connect components irrespective of material. In our e-textiles projects we have seen students choose between all of these skills.

A number of different factors impact selection for a given project in this complex calculus of skill selection. The relative strength of a maker's skill come into play; a maker might excel at sewing compared to painting or vice versa. Different skills have different aesthetic components; thread and paint have different appearances on material. Furthermore, different techniques are more appropriate for some materials than other—insulated wire is more appropriate on a metallic material. LEDs for Lilypads have built in resistors, which make them desirable for having fewer visible components, whereas in painted circuit the width of the painted lines limit resistance similarly affecting the aesthetics of the result.

We contend however, that gender presentation, plays an additional role in this calculus. If skills are gendered, then so is performing them in a gendered environment. Fox et al. [24.] and Toupin [57.] show that maker spaces marginalize women. By extensions women's successes in executing skills may depend on the gender dynamics of the maker spaces around the skill in question. Huff's study for instance, showed young women performed worse on programming tasks when done in the presence of young men [27.]. Women in maker spaces may well also perform worse on masculinely gendered tasks in presence of men, and similar tensions might play roles in other gender constructions. We know our young Turkish boy in Maker Space B would not sew because it was a girl's skill, but once the other boys started he followed suit. Similarly, the boys in the Maker Space A all avoided doing soft circuits. Thankfully, however, symbolic gender can change. In the case of these boys the issue was overcome easily once they realized they were making something they could take with them. Regardless, while not the only factor impacting skill use, symbolic gender influence what skills a person has, and under what circumstances they are used.

4.3 Individual Gender

Individual gender, how one chooses, to position one's own gender identity manifests itself in several aspects of making. In particular, we focus on what project they select, and how they characterize their identities as makers.

When an individual selects projects, we contend their individual gender self-expression comes into play. In the Maker Space B, we saw girls constructing projects in keeping with gender roles. Girls created birds that lit up when the returned to the nest, or the rabbit whose tummy glowed when it was 'fed' a carrot. These emphasized normative feminine tropes like nurturing. Our boys however used soccer motifs or remixed the rabbit project as a shark attacking a rabbit complete with LED blood. We do not intend here to reify binary gender by mapping projects to genders, rather to point out the children had their choice of project and choose to create variants that expressed their gender identities. Children in our study expressed masculine and feminine identities that were not directly mapped to biological sexes.

Similarly, expressions of expertise allow for the expression of individual gender characteristics. Masculinist constructions of structural gender are in part linked to binary and asymmetrical divisions between masculine and feminine individual gender identities [7.] [10.] 27, [44.]. Feminist HCI discussions of gender and technology relations have revealed traditional masculinist computing cultures often construct masculine abilities as technical and expert [6.] [17.] [63.] [64.] and feminine capabilities as nontechnical and amateur. This construction is potentially problematic for a person who wishes to be feminine and technical, and places considerable social pressure on gender and technical identity construction. Maker culture values have the potential to dismantle these rigid categorical distinctions, with their emphasis on nonlinear learning processes such as bricolage, or learning by doing, [28.] [63.] and the collapsing of 'black box' hierarchies [9.] [17.] [64.] that allow for a varied spectrum of skill building to emerge. This also promotes the idea that within maker cultures gender identity plays a role in both the performance of and the perception of agency. This is because maker cultures in particular "create a space that is flexible enough to keep the discussion open as to who we might turn out to be" [33.] p. 437]. This generates opportunities to individuals to construct non-binary gender identities that they devise instead inscribes "identity through the new sociotechnical initiatives that we devise[33.] p. 437]. Thus, spaces in particular reveal areas in which bricoleurs and makers might attempt to engage in both masculine and feminine skill building. This in turn would allow for sociotechnical identity formation that expands beyond masculinist restrictions that obscure in particular feminine sociotechnical identities and femininely gendered soft skills [29.][48.][63.]. Maker spaces ideally create environments whereby there are "alternative framings of the user as creative appropriator" [3.] and allow for contexts that represent a range of gender identities [49.] [53.] [54.] [55.] [63.].

Ethnographic research into feminist maker values have begun to emerge within HCI literature [28.] [57.] [63.] who have researched hackers in terms of sociotechnical identity formation. Toupin's work on feminist maker and hacker spaces illuminates how even the maker ethos at times can be construed as masculinist and reductive [57.]. At the same time, our findings illustrate that maker culture has the potential to sustain a broad gendered spectrum of sociotechnical skills and identities. Our work here reinforces earlier work that gender has a performative dimension [16.][43.] [44.] [63.], and supports Rode and Poole's model of Sociotechnical Gender and Technical Identity Co-Construction [48.]. Our ethnographic work with the children's maker spaces in Germany reveals that skill building occurs in gendered contexts, in tandem with gendered performances of technical ability, impacted by both the tools used [56.] [63.], and the artifacts that are constructed as a result [28.] [63.].

5 DISCUSSION

Makers make objects that are imbued with rich social meanings as discussed in length in the material culture literature [13.] [36.] [37.] [38.]. Objects act as discussed by Turkle in that they "are able to catalyze self-creation" [59.]; we construct our identities in relation to them [44.]. Feminist STS (Science and Technology Studies) scholars [18.] [22.] [62.] have discussed a notion of Technology as Masculine Culture, that technology that is designed by men (or more correctly rather those with masculine values), better reflects masculine needs (than those of women with feminine gender identities). This is problematic because men represent the majority in maker culture but also the objects they create in turn become gendered as masculine [10.] [61.]. Given technology is often masculine culture despite being used by women with feminine individual gender identities, Faulkner problematizes women with feminine gender constructions [23]. She discusses the problem of gender inauthenticity, when an object's symbolic gender goes against structural gender norms, creating a conflict of individual gender identity [18.] [22.] [62.].

We posit gender inauthenticity can be a problem for some women in maker culture. Not all women engage in more normative expressions of feminine individual gender identity, but many perhaps even the majority do. While we are arguing for a place for women with feminine gender identities, it is equally important that people with all types of non-binary gender identities fell welcome.

Thus, our goal is to demonstrate the terminology put forth in Rode and Poole's Sociotechnical model of the co-construction of technical and gender identity help characterize the tensions that go on in maker culture. We have shown how gender identity construction occurs in response to factors on the individual, symbolic and structural gender level. Further, we have shown that technical identity is also complex, and that a full understanding of technical ability, self-efficacy, and presentation of gender are required to truly understand how a person responds to technology. These gender and technical identity constructions occur in concert. Further, we emphasize that teasing out these factors is critical to addressing the gender equity issues in maker culture, which in turn might attract more women to maker culture and by proxy STEAM.

6   FUTURE WORK & CONCLUSION

Here we have focused on gender, but the issue of diversity is broader. Scholars outside of HCI have also accused maker culture of supporting colonialist, ablest, heteronormative, white masculinist traditions of sociotechnical identity formation; these can manifest for example in Steampunk communities that support the maker culture ethos in broader dimensions than previously studied [53.] [54.] [55.]. These other aspects of identity require closer examination in light of intersectionalist perspectives [e. g. [64.]. Maker culture values potentially allow for artifacts and technical identities that support non-binary gender constructions [62.]. Thus, maker values allow for a range of technical identity constructions [31.].

HCI research into maker culture has expanded upon the notion as Silver observes that "mutation, not replication, is the normal expectation" [49.] p. 244]. Mutation" [49.] p. 244] in this instance refers to innovation in terms of skill building, identity formation and the creation of sociotechnical artifacts. This trifecta indicates that the maker ethos addresses multiple dimensions of innovation within sociotechnical contexts. This maker "mutation" [49.] p. 244] also disrupts conventional stereotypes of gendered skill building, that in turn refutes technical knowledge as a masculinist domain.

Some scholars within HCI have conducted ethnographic studies of various maker communities of practice in a desire to fathom key ways in which maker values might be applied within traditional computing cultures [3.] [5.] [54.] [56.]. The radical belief that amateurs can become experts has been explored in these ethnographic examinations of maker spaces in particular [55.] [56.]; this allows for the recruitment of girls into STEM [18.] [22.] [62.]. Our model expands the dimensions with which we might understand how children in particular, who are being indoctrinated into their gender roles through play and exploration [1.] [63.] might discover new ways as makers to defy, rather than accommodate, binary sociotechnical gender identities. As a result, children continue to be a crucial component of understanding how maker culture supports democratic practices, and approaches to human and technology relations as an emancipatory context [6.]. Furthermore, as some researchers have begun to correlate cultural and ethnic identities as integral parts of sociotechnical gender identity formation [1.] [28.] [63.] our work with children can help us understand how to help non-binary gender performances become visible and valid; these identities cannot be obscured if we wish to see more diversity within STEM and cannot be obscured if we wish for collaborative and varied maker spaces.

Artifacts play a crucial role in sociotechnical identity formation [59.] pg. 9] as the production and contexts of use mediate constant negotiation of sociotechnical gender identities as they change and shift; we can then assert that sociotechnical identity formation has multiple layers. This gendered infrastructure of symbolic, individual and structural categories and performances expands beyond binary gender categories through the unpacking of how masculinist maker values might inhibit and disrupt the construction of feminine sociotechnical artifacts, skills, and identities, as Rode and Poole's sociotechnical gender taxonomy demonstrates. Furthermore, binary constructions of gender identities, taking into consideration further classifications that include ethnic, racial, able bodiedness, and sexual orientations, within both conventional computing environments as well as maker cultures [24.] [57.] can position feminine identities as both passive and unskilled, and therefore invisible. Our work calls this into question at the individual, structural, and symbolic levels, as all of these factors impact sociotechnical gender identity formation. We have shown that using the model of Socio-Technical Gender Identity allows for more nuanced discussion of these issues, in ways that allow us to investigate and understand how maker culture values might support a diverse spectrum of sociotechnical identities and how we might understand various facets of how this spectrum emerges within sociotechnical

environments, such as maker spaces. Feminist maker values resist binary constructions of gender and expertise [2.] [9.] and instead support the gender classification of femininity as an active agent, that contributes meaningfully to the potential for designing emancipatory practices that support the emergence of a multitude of sociotechnical identities.

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