# "It's always been a challenge, right?" An analysis of the affordances and limitations of STEM educators' attempts to improve gender equity in Global South and North makerspaces

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**Introduction:** The longstanding, chronic under-representation of girls/ women and non-binary youth in engineering and computing remains a global concern. Informal STEM learning contexts, such as makerspaces, have the potential and flexibility to engage all young people with STEM in creative, engaging and equitable ways. Yet to date, this potential remains largely un-realized, with many makerspaces remaining 'chilly', male-dominated spaces (materially, spatially, relationally and socially). This paper seeks to contribute to understanding of the challenges and possibilities for more gender equitable practice in makerspaces.

**Methods:** The paper analyses multimodal data collected by academic and youth co-researchers over two years from two Global North and two Global South makerspaces, as part of a collaborative research-practice partnership project.

**Results:** The paper considers educators' attempts to evolve and improve gender equitable practice in their settings, shared challenges and barriers to gender equity, steps taken by practitioners to support greater gender equity within their settings (through access/outreach, governance/staffing and pedagogy) and the challenges and blocks they encountered to progress.

**Discussion:** Implications are discussed for advancing equitable practice to support the participation of girls/ young women and non-binary youth within STEM and makerspaces.

KEYWORDS

gender, equity, makerspace, practice, youth, practitioners

## Introduction: gender inequity in STEM and makerspaces

The longstanding, chronic under-representation of girls, women and non-binary youth in engineering and computing remains a global concern (e.g., UNESCO, 2021). This issue persists across educational levels, from early years to higher education and industry and is found within both formal and informal STEM learning settings (e.g., Fisher et al., 2016; Soe and Yakura, 2008; Vitores and Gil-Juárez, 2016). While the exclusion of non-binary and trans young people are important forms of gender injustice, in this paper we focus primarily on

gender equity issues relating to young people who identify as girls, women and female,[1] although where our data allow, we also include non-binary youth.

Internationally, engineering and computer science remain acutely male-dominated areas of education and employment. These fields are also the focus of considerable policy interest, due to their economic importance and capacity to help address urgent global challenges. Yet these fields have also been identified as facing both current and future predicted skills gaps and as urgently requiring the talents and perspectives of a more diverse workforce. There is thus considerable interest in understanding how to increase and diversify participation in engineering and computer science. Informal STEM learning contexts, such as makerspaces, have the potential and flexibility to engage young people with STEM in more creative and impactful ways than mainstream education, when enacted in equitable ways (Bell et al., 2009; Bevan et al., 2018; Canfield et al., 2020; King et al., 2021). Yet arguably to date this equitable potential has remained largely under-realized, with widespread gender inequalities in engagement and participation within makerspaces (e.g., Bean et al., 2015; Eckhardt et al., 2021; Achiam and Holmegaard, 2017; Dawson et al., 2019; Tran and Gupta, 2021).

Much of the research on gender and makerspaces comprises small-scale, qualitative studies conducted in the Global North with between one and ten adult women from a single space, often either HE students and/or adult women makers (e.g., Bean et al., 2015; Hedditch and Vyas, 2021; Keune and Peppler, 2019; Kjartansdóttir et al., 2020; Lam et al., 2019; Shinnick, 2019). This work has largely focused on documenting the distinctive attributes, qualities and experiences (Tomko et al., 2021) of these 'pioneering' (Bean et al., 2015), 'self-determined' (Shinnick, 2019) women and has drawn attention to the numerous benefits derived from participation [such as personal development and growth, increased connection/ commitment to STEM (Keune and Peppler, 2019), agency and fulfillment (Kjartansdóttir et al., 2020), access to resources, learning, confidence (Lam et al., 2019), and social connections (Shinnick, 2019)]. There remains a paucity of research on gender in/equity in makerspaces in relation to girls/young women, non-binary youth, practitioners and different types of makerspace including those in the Global South (Eckhardt et al., 2021). This paper aims to add to understanding of how practitioners might foster greater gender equity to better support the participation of girls/young women and non-binary youth within global north and south makerspaces.

Attention has been drawn to how makerspaces are often experienced as western, masculine spaces (e.g., Vossoughi et al., 2016), reflecting not only the gender and racial identity of the majority of participants but also socio-material features of the space itself. For instance, spaces are gendered through, the design of the physical and social space, the sorts of attitudes, terminology and language

commonly deployed, the nature of machines, tools and objects (Eckhardt et al., 2021; Shinnick, 2019) and through the dominant cultural and gendered roles, expectations and types of learning that are supported and normalized (Hedditch and Vyas, 2021). Lam et al.'s (2019) study of women engineering students in a university makerspace found that they experienced considerable gender bias, as well as intimidating, hostile, and non-inclusive environments. Gendered microaggressions (Sue, 2010) were also common, such as when male participants tried to control women's projects and/or doubted women's competency in the space, even when the woman in question was highly proficient (e.g., with multiple years of experience in using a particular machine). Other studies have noted how men tend to be more mobile within makerspaces and how conventional makerspace technologies are perceived in gendered ways, associated with either masculinity or femininity (Melo, 2020). Women in other studies have also reported experiencing explicit sexism, such as being made to feel incompetent and inferior by male peers (Shinnick, 2019).

Many interventions aimed at increasing women's participation within STEM fields focus on trying to support, influence and/or change the attitudes and experiences of women. However, it has been argued that such deficit approaches are unhelpful, locating both the 'problem' and 'solutions' within women/girls while failing to address the wider gender (and other intersectional) inequities that create and sustain uneven participation patterns (e.g., Archer et al., 2023). For instance, attention has been drawn to how the dominant culture within STEM fields has normalized and reflected the identities and values of the privileged – but particularly white, middle-class men – with women's and minoritized communities' interests, identities and knowledges being routinely excluded, marginalized and/or appropriated (e.g., Eglash et al., 2004). In contrast, social justice-orientated, community-based initiatives have explicitly centered the values, identities, knowledges and technologies of the excluded (e.g., Calabrese Barton and Tan, 2010; Vossoughi et al., 2016). Such approaches focus on changing the dominant culture and practices of STEM, calling out unjust practices and relations and reclaiming, resisting, re-appropriating and asserting alternative approaches to STEM. They also value inclusive forms of STEM-rich making, as exemplified within feminist hacker communities and indigenous STEM making, which focus on broadening conceptions of what and who 'counts' within STEM and the value of STEM-rich making for social action (Foster, 2019).

The literature identifies four main areas for supporting gender equity within makerspaces and informal STEM learning settings. First, attention is drawn to the importance of supporting practitioner awareness of gendered language, practices and stereotyping. Studies underline the value of professional development to support understanding and critical reflection among staff so that they can identify and address the reproduction of gendered practices and injustices, such as through gendered behaviors, expectations, roles, language and stereotypes within makerspaces (e.g., Eckhardt et al., 2021; Shinnick, 2019), developing awareness of the ways in which "language, tools and terminology" are gendered (Hedditch and Vyas, 2021, p. 12). Second, the literature highlights the value of supporting participant agency, power and social action through STEM-rich making. For instance, studies show how young people's agency can be supported through opportunities for playful tinkering and project design (Keune and Peppler, 2019), when participants are facilitated to set their own goals (Dayton, 2017). Gender equity can be enhanced

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1  Our conceptualisation of gender is grounded in feminist post-structuralist theory (e.g., Butler, 1990), in which gender is understood as an ongoing, embodied performance that is not reducible to a particular biologically sexed body and in which both sex and gender are understood as fluid and not limited to the binary of male/female. We use the terms girl, (young) woman and female interchangeably to refer to those who identify and align themselves with femininity.

through collective, community-based (Foster, 2019) and cooperative, team-based learning that centers participants' experiences, interests and needs and links to their personal passions (Tomko et al., 2021) and/or community issues (Vossoughi et al., 2016). Such approaches focus on the process rather than the end product or technological outcomes (Pasquini et al., 2020), supporting distributed creativity and development (Richard and Giri, 2017) to address social injustices (Calabrese Barton and Tan, 2010) and gender stereotypes (Dayton, 2017). Gender equitable pedagogies use assets-based teaching and learning approaches that value and elicit the STEM expertise and experiences of traditionally underrepresented youth (Keune and Peppler, 2019).

Third, the literature emphasizes the importance of centering gender within STEM making – ensuring that programmes, topics and projects are grounded in the lives, needs and interests of girls/women and non-binary youth and address topics such as feminism, gender, sexuality, and society (Rogers, 2017). It has been argued that interdisciplinary approaches (Dayton, 2017) to making and crafting can help disrupt gendered binaries between STEM and creativity (Richard and Giri, 2017) and broaden dominant masculine notions of STEM. It has also been suggested that learning experiences and pathways need to be designed in ways that "cater to different levels of digital literacy" (Hedditch and Vyas, 2021, p. 12), especially to support novice participants from non-traditional backgrounds.

Finally, attention has been drawn to the need for makerspaces to engage critically and meaningfully with issues of gender representation and role models. This includes the need to recruit more gender diverse staff, tutors and role models (Spieler et al., 2020), especially in senior and leadership roles (Eckhardt et al., 2021), who can act as mentors for women/girls (Dayton, 2017) and non-binary youth. Calls have been made for greater support to be given to practitioners to help them address inequitable forms of representation in their spaces and practice, including centering representations of female STEM-rich making within makerspaces through "long-term display of artifacts in physical makerspaces" (Keune and Peppler, 2019). It has also been suggested that more needs to be done to foster meaningful social interactions and relationships (with peers, significant others) that can expand gender under-represented young people's access, leadership, and visibility toward fuller participation in makerspace communities (Tomko et al., 2021).

However, less is known about whether these areas are relevant within youth programmes in both global north and south makerspaces and what sorts of affordances or challenges practitioners may encounter when trying to put gender equity approaches into practice. In this paper, we seek to contribute to understanding of how makerspaces might advance gender equity in their youth programmes. To do so, we analyze data from four different international makerspaces that were trying to disrupt gendered cultures, practices and relations in their setting to better support the participation of girls, young women and non-binary youth. Specifically, the research asks:

- What are the shared challenges and barriers to gender equity identified by practitioners and young people across the four spaces? How/do these differ by context?
- What steps did practitioners take to try to support greater gender equity within their practice and programmes? How successful, or not, were these felt to be?

- What were the challenges and blocks to progress?
- What are the implications for supporting gender equity in STEM and makerspaces globally?

## Methods

This paper reports on data collected as part of The Making Spaces project, a four-year, international research and development partnership project between university researchers, makerspace practitioners and young people from six international spaces. Over the course of 2 years, staff undertook professional development workshops and an online training course to develop their understanding of equity. Through discussion, practitioners selected aspects of their practice that they wanted to develop and iterate further, supported through regular critical reflection sessions with researchers and colleagues.

This paper reports on multimodal data collected from four of the six spaces by 4 university researchers and 28 youth co-researchers, including observation recordings, field notes, interviews, group discussions and text programme analysis to document the experiences and perceptions of practitioners and young people. Through workshops with university researchers, youth co-researchers shared their views and experiences of gender inequity, co-developed research questions and co-designed research tools. Youth then conducted some of the fieldwork and helped co-analyze data (see below).

We first introduce the four makerspaces, then provide details on the participants, data collected and analytic approach. For reasons of anonymity, we identify spaces only as City North or South, to try to protect the identities of individual participating practitioners and youth.

## The City North makerspaces

The City North makerspaces are located in cities in two different central and northern European countries. Both spaces are funded through a mixture of government, charity, industry and NGO grants. One of the spaces occupies a floor of a renovated warehouse and comprises a small laboratory, a hands-on workshop, a small lounge/relaxation area with refreshment areas and a multipurpose space. The other does not have a permanent physical space but works in an urban area of high deprivation through online programmes and through the use of rented local physical spaces, such as community centers. Over the course of the project, this makerspace also started to rent arts spaces, as a way of further challenging stereotypes around the masculinity of tech. As one practitioner explained, "We avoid the stereotypical tech environment, opting instead for a cultural venue … This avoids placing learners in an environment that is predominantly male and moves them to a more inclusive environment [that is] staffed predominantly by women."

The demographics of the two makerspaces vary, reflecting their respective locations. One setting caters largely to local white, middle-class families and, prior to the collaboration, predominantly boys/young men. The other serves a mix of low income, predominantly white (but over time including more racially minoritised) and gender diverse young people. They both run a range of adult and youth programmes, largely focusing on digital and/or engineering skills, including coding and/or addressing environmental and social themes.

Some of the programmes also employ arts/creative approaches. Typically, each makerspace offers free c.10-week youth programmes (one space focusing on 8–17-year-olds and the other on 18–30-year-olds). The younger youth programmes tend to follow a standard 'recipe' of facilitator-led input and pre-determined hands-on activities. The older youth programme focuses on developing unemployed and underemployed young people's understanding, skills and practice of website development, using HTML, CSS, and JavaScript. It also provides career support, such as CV and interview advice, in the digital industry. Both programmes also offer some whole or half day occasional (e.g., weekend/summer holiday) programmes, ranging from single taster sessions to whole day events. In both spaces, sessions are facilitated by adult staff and involve peer mentors (drawn from previous long-term youth programme participants).

## The City South makerspaces

The City South makerspaces are located in cities in two different Asian countries in the Global South. Both spaces are predominantly funded through international donor agencies, with one also receiving some national funding. One of the makerspaces occupies the upper floor of an office building and comprises a multipurpose classroom space and storage areas but also operates remotely, providing mobile outreach opportunities across the region. The other is located in the business hub area of a large city, constructed from donated and recycled materials (such as shipping containers) as part of post-natural disaster reconstruction efforts.

In terms of participant demographics, both spaces' participants come from local, low-income families. Prior to the collaboration, participants in both spaces were predominantly boys/young men. Both offer their youth programmes free of charge and run a mix of one-off and longer-term youth programmes, largely focusing on digital and/or engineering-based making, orientated toward addressing local environmental and social issues. One of the spaces has a longer experience and history of running youth programmes, whereas this is a recent development in the other space, that had predominantly worked with university students and adults. Both makerspaces partner with local schools to recruit participants for their programmes. Both spaces have developed c. 10-week youth programmes (for 8–17-year-olds), running either during school time or via after-school sessions. The more experienced space also offers one day and short-term programmes both at its main site and remotely. Prior to the start of the project, both spaces tended to offer fairly prescriptive programmes, facilitated by adult staff that followed a standard 'recipe' of facilitator-led input and pre-determined hands-on activities.

## Participants and data

This paper reports on multimodal data from practitioners and young people from four makerspaces. As detailed in Table 1, this data included 62 youth interviews, 25 practitioner interviews, 71 practitioner feedback/reflection meetings, 17 youth discussion groups, 44 observations of practice within makerspace sessions and a small number of interviews with parents and practitioner surveys.

TABLE 1  Summary of data collected and analyzed across the four makerspaces.

| Data | Number | Data collected by (University researchers, UR/ Youth Co-researchers, YCR) |
|---|---|---|
| Youth individual and paired interviews | 62 interviews with 55 youth | 14 UR; 48 YCR |
| Practitioner interviews | 25 interviews with 16 practitioners | 21 UR; 4 YCR |
| Parent interviews | 6 | YCR |
| Observations of practice | 44 | 37 UR; 7 YCR |
| Practitioner feedback/ reflection meetings | 71 | UR |
| Youth discussion groups and workshops | 17 | UR |
| Short endline practitioner survey | 13 | UR |

Practitioners ranged from early career to highly experienced and represented a range of roles, including volunteer facilitators, paid programme leaders and managers and represented different genders, racial/ethnic, religious and social class backgrounds. The children and young people ranged in age from 8 to 30 years old (with youth coresearchers ranging from 15 to 28) and similarly represented a range of gender, racial/ethnic, religious and social class backgrounds.

## Analysis

To maintain a manageable focus and discussion, we address gender equity in relation to makerspace participants who identify as girls/young women and the very small number of non-binary youth. However, we recognize, as noted by Eckhardt et al. (2021), that this focus still poses "a significant risk of reproducing gender as a binary construct by neglecting its complexity as culturally and socially constructed." (section 2.3). Conceptually, we recognize the socially constructed, complex, fluid and performative nature of gender identity and identification, which extends beyond a male/female binary and treats gender as an ongoing performance that is never fixed, essentialized or 'achieved' (Butler, 1990). While we maintain a central focus on participants who identified as girls/young women, we also in places discuss makerspace practitioners' approaches to gender equity when these included non-binary youth, noting that not all settings recognized or were aware of having non-binary identifying participants. While we foreground gender in this paper, our theoretical framework understands gender as inseparable from other axes of identity and inequity, such as race/ethnicity, religion, social class, disability and sexuality – that is, we follow an intersectional (Crenshaw, 1989) approach to gender.

Through a series of dedicated facilitated workshops in each makerspace, academic researchers and 28 youth co-researchers

(YCRs) met to conduct the data collection and analysis. YCRs undertook initial thematic analysis of the data that they had collected, producing mind maps and posters of the key themes and findings, discussing these with the academic researchers. The academic researchers then looked across the whole data set, synthesizing, iterating and combining codes, where appropriate, to produce a next iteration of the codes. These were then brought into dialogue with the literature to produce a set of draft findings, which were then discussed with participating practitioners with a final round of refinements before being finalized.

# Results

We begin by discussing some shared challenges and barriers to gender equity that were identified by the practitioners and young people from the four spaces. We then consider the steps that practitioners took to try to support greater gender equity within their practice and programmes in terms of access and outreach, governance and pedagogy (as summarized in Table 2). We conclude by considering some of the challenges and limitations that practitioners experienced to enacting gender equity within their spaces.

TABLE 2  Summary of key steps taken by makerspaces toward gender equity.

| | Access and outreach | Governance | Pedagogy |
|---|---|---|---|
| Gendered language, practices and stereotyping | Address gendered language and representations in marketing materials, including running through gender text decoding programmes and via youth advisors | Checking and challenging normative masculine language and terminology | Checking and challenging normative masculine language and terminology |
| | Welcoming and respecting pronouns | Welcoming and respecting pronouns | Normalize and systematize asking for pronouns |
| | Regular and sustained critical reflection on gender equity by practitioners | Use of critical reflection tools by leadership | Regular and sustained critical reflection on gender equity by practitioners |
| Agency, action and power-sharing | Use feedback from diverse participants to inform future design and practice | Active gender staff/volunteer recruitment strategies | Female-led programmes and workshops |
| | | Ensure women and non-binary people included meaningfully in power-sharing and governance | Focus on supporting participant agency, community social action and voice (not just 'hard' STEM skills), addressing topics of relevance and meaning for female and non-binary participants |
| | | Female youth board chair invited to main governance board | |
| Centering girls/women and non-binary youth | Centering the identities, experiences, knowledges and needs of girls/women non-binary youth when designing/delivering outreach | Centering the identities, experiences, knowledges and needs of girls/women in the organization | Centering the identities, experiences, knowledges and needs of girls/women and non-binary youth in pedagogy. Using assets-based approaches |
| | Deliver courses in 'feminized' spaces | | |
| | Reserving given % of spaces for girls and non-binary youth on courses and/or single sex offers | | |
| | Ensure promoting gender inclusive workshops and offers (e.g. focal themes, how conveyed) | Ensure offers are relevant and engaging for girls/women (addressing their interests, needs, lives) | Ensure offers are relevant and engaging for girls/women and non-binary youth (addressing their interests, needs, lives) |
| Representation and role models | Visibility of girls/women and gender diverse people in materials | Intersectional role models and mentors | Attention to the gendered nature of physical, social and discursive spaces |
| | Visibility of diverse staff and role models, including guest speakers, volunteers and mentors | 'Realistic and relatable' peer role models/mentors | Gender audit of courses and offers for (unconscious) gender bias |
| Individual, family and community capital | Taster days, peer-to-peer meet ups | Ensure offers are sufficiently resourced to address and meet the needs of all youth | Inclusive practices to ensure all participants' intersectional needs are met (e.g., food, transport, breaks, access to equipment etc) |
| | Family welcome/information sessions, talking with parents to build familiarity/ understand and address concerns | Ensure community links and representation on governance boards | Sessions are inclusive of families and communities |

## Shared challenges and barriers to gender equity

Despite their different geo-political and social locations, all the makerspaces had programmes that historically tended to heavily over-recruit boys/young men – a trend that the practitioners had found difficult to shift. The makerspaces identified a number of similar challenges to advancing gender equity, namely: general societal associations of STEM with masculinity; family and cultural values and practices in relation to girls/young women; recruitment channels that favored boys and male staff and participant attitudes and behaviors. These are now discussed in turn.

### General associations of STEM with masculinity

Practitioners and young people felt that, irrespective of their different national contexts, a global cultural alignment of STEM with masculinity made many makerspace programmes more attractive to boys and less appealing to girls and non-binary youth. As one of the young people from a City North makerspace explained, "there is a little more boys [here] just because this stuff is usually connected with electronics and stuff like that, so it attracts the male gender." Parents who were interviewed by youth co-researchers at City North also how their daughters had been put off or dissuaded from attending or signing up for a course that was perceived to be what one termed as "a male topic" (Parent, City North):

> "The topic [of the workshop] is also such that it implies that there would likely be boys, and because of that, she may not want to be as brave about wanting to be here." (Parent, City North).

### Family and cultural values and practices in relation to girls/young women

Practitioners in both City North and South makerspaces felt that the association of STEM with masculinity was reproduced within families in ways that involved the active dissuading and discouragement of girls, specifically, from participating in makerspace programmes (the issue was not raised in relation to or by non-binary youth). For instance, practitioners in a City North makerspace recounted an experience when a father came to a taster event with his son and daughter but only encouraged the son to engage, telling staff that he was "really good at tech." When staff tried to engage with his daughter too, he replied "oh, she's rubbish." As the practitioner reflected:

> "Immediately he [the father] was only talking about his son …. It was really obvious that he was pushing his son … I was really encouraging the girl and she loved it and it was like this lightbulb moment of 'oh someone thinks that I can do this as well' rather than a predetermined assumption that this wasn't intended for me, I was only here for my brother."

Practitioners and young people in both City North and South spoke about some parents pressuring girls not to attend after-school programmes due to concerns about girls' educational progress and other duties, which one City South practitioner termed as some parents being 'not so open-minded.' Some young women from City North also recognized this issue, which manifest as parents telling their daughters not to attend:

> "I love coming to [makerspace]. However, it is difficult to manage the time. It is because the exams of 12th grade are coming soon. Before my parents used to encourage me to come here. However, they now tell me to manage my time for coming here. I had enough time before. Now, I have to study for the exams. Therefore, my parents tell me not to come here." (Young woman, City North).

While the challenge of balancing study and leisure activities theoretically applies to all young people, it was notable that the issue was only referred to as impacting the attendance of girls.

In the City South makerspaces, practitioners and young people felt inequalities in participation were exacerbated by dominant local cultural and/or religious norms that restricted girls to the domestic sphere. Within large, low-income families, daughters were commonly obligated to undertake extensive cooking, cleaning and childcare for younger siblings, restricting their capacity to participate in after-school programmes. Young women felt particularly strongly on this issue:

> "Although STEM is very important for both genders, females tend to face more problems, more issues when they try to learn about STEM and use it in their lives. So young girls do not have the same opportunities as young men throughout the fields of STEM education. Sometimes the programmes places have are less for females or they are not eligible. […] society expects less from ladies, therefore treatment varies between both genders, society does not expect for women become a scientist or an astronaut, they are just expected to be cooking at home." (Young woman, YCR, City South).

> "Society sees that education is useless for women – in the future you are just going to marry so you will not use your education that you got. So, many time women do not continue with their education." (Young woman, YCR, City South).

In City North and South makerspaces, parents and some young women were also concerned about the personal safety of girls when traveling to/from after-school programmes, further restricting participation. As practitioners explained:

> "Because here in [country] its acceptable when the boys come back from this center after 4, 5 o'clock … but the girls is harder. But we will work on this."

> "[They] say [girls] have to stay at home."

One young woman also requested on-line attendance at City North sessions as she was concerned about traveling alone to and from the makerspace in the evening when it was dark. No such concerns were raised by or voiced in relation to the attendance of boys or young men in makerspace programmes.

## Recruitment channels

Gender inequalities in recruitment processes were identified as resulting in more boys than girls and non-binary youth enrolling on makerspace programmes. For example, City North practitioners

recognized that many participants were recruited through social connections and personal recommendations of existing participants, a process that they felt exacerbated gender inequalities in access, as boys tended to recruit other boys. In City South makerspaces, staff felt that these gendered stereotypes were also promoted within the education system, which negatively impacted attempts to recruit girls, specifically, to makerspace programmes. As one practitioner put it, "The thing that most surprised me is that [name] school, they will send 7 boys and just one girl [to our programme]. This is what we call the gender gap. They have not good idea about girls and science." The prevalence of such views was also underlined by a City South government ministry of education, that insisted on gender segregation within educational programmes as a condition of their funding ("[They said] you will sign that you will never make the boys and the girls go in one session").

## Male staff and participant attitudes and behaviors

Gendered interpersonal behaviors by boys within sessions were identified as limiting and restricting participation and engagement among girls and non-binary youth. For instance, in one of the City North makerspaces, observation data from programme sessions indicated that boys tended to dominate class discussions, social interactions and facilitator attention. Young people and parents also concurred:

> "Us girls are quieter" (Girl participant, City North).

> "But if there are many more boys than girls, then they [girls] get scared and do not even approach. Because boys are so much braver and so much louder and so much more active that then girls prefer to stand by and watch." (Parent, City North).

None of the youth participants reported experiencing any explicit instances of sexist talk or behavior, instead gender inequalities were revealed through more subtle forms of gendered behavior (e.g., Sue, 2010). For instance, quantitative analysis of observation data conducted by one of the City North youth co-researchers revealed that male learners were more likely to speak out during sessions compared with girls and non-binary participants. Their data revealed that 27% of male-identifying participants spoke and offered input, views or opinions during the session, compared with just 7% of female and non-binary identifying learners, who tended not to speak publicly unless addressing a direct question or problem from the facilitator. Similar patterns were noted within City South spaces, where practitioners described quieter behavior and participation (being less likely to "speak up") among girls, which some practitioners attributed to socialization practices within "traditional families." As a result, practitioners recognized that they "cannot force her [girls] to speak up" but instead need to create a supportive context that is "mindful" of these prior experiences while also seeking to support girls to exercise voice and agency with the hope that this "might ignite something" in them.

In some of the settings, a small number of staff members articulated somewhat stereotypical views around gender and/or conveyed a lack of awareness of gender equity issues when interviewed. For instance, a City South practitioner explained that "The girls are not interested in science and this kind of work. The boys are more interested… we have a problem with girls coming here." Similarly, a

City North practitioner reflected on a male-dominated programme, saying: "There are still a lot of boys, we have only these two girls for now. I mean, it's about robotics, so I guess, all the boys are interested! (laughs)." Fieldnotes from the first session in a City South session youth programme also recorded how the introductory PowerPoint presentation given by a male practitioner contained only images of boys/men using lab equipment. The staff member in question remained unaware of the gender bias in his materials, despite the workshop being the first in a new programme that had specifically targeted girls and young women and hence mostly comprised girls.

# Taking steps toward gender equitable practice

## Steps toward gender equitable access and outreach

While the existing literature does not focus much on gender equitable access and outreach, this was an area that all the practitioners identified as an important focus for improvement. All of the makerspaces identified ways that their access and outreach practice could be made more gender equitable to better reach and engage female and non-binary learners, although, as discussed below, the specifics (of issues and adapted practices) varied according to their different sociocultural contexts.

## Gendered language and representation in outreach materials

City North practitioners identified that their prior advertising and marketing materials had unwittingly been written in ways that normalized masculinity, such as through the use of masculine language, imagery, pronouns and in the choice of session topics and themes. They decided to re-write their promotional materials (e.g., adverts, social media posts, course publicity materials), using female pronouns and grammar, foregrounding girls/women and non-binary people within imagery and representations and introducing more gender equitable workshop themes (e.g., focusing less on technical aspects and more on social and environmental applications). As the following practitioner reflected, the change was noticed by participants and led to extensive discussions within the space between participants and staff, which in turn helped practitioners to identify further ideas and iteration points to improve the participation of girls/young women and non-binary youth within the space:

> "The announcement for the workshop was written in the female gender. This was also noticed by the participants, who asked at the beginning of the workshop why we did this and we established great debate about that. They also talked about gender differences at the workshop, how they could attract girls to the workshops, why they think there are more boys in science jobs" (City North practitioner, reflection form).

The other City North space also increased the visibility of women, trans and non-binary youth in their marketing materials, including more gender diverse images and ensuring that these represented both white and racially minoritized communities. They named women staff on their course materials and website, included

quotes from female and non-binary course alumnae and ran workshops in a cultural/arts, female-run venues. They also integrated project-based challenges into their courses that focused on supporting local women's organizations. One of the YCRs conducted a further analysis of the programme website and promotional text, which including running this text through a gender text decoder AI programme, which judged the text to be 'strongly feminine-coded.' In addition to focusing on making their materials more female-centered, the practitioners also undertook a range of actions to ensure that non-binary and trans youth felt similarly represented, welcomed and included. For instance, they ensured that all sessions started by asking for people's pronouns, which were added to name badges. They ensured that both women and non-binary peer mentors supported workshops and they partnered with local LGBTQ+ organizations to further inform their practice and outreach work. They also conducted workshops to further understand community interests, wishes and needs and to get feedback on their evolving practice.

One of the youth coresearchers interrogated the marketing strategy for City north, concluding:

> "I reviewed the marketing strategy, looking at who [City North Makerspace] partnered with to advertise. I think it's a good strategy to get involved with organisations that help women. Partnership organisations have been thought about e.g., [charity name] that supports unemployed women and [charity name] that supports girls into getting in the tech industry. This has been thought about to show that they are move gender inclusive and support women."

## Gender quotas and targets

Both City North makerspaces introduced gender participation strategies for some of their most popular programmes, which tended to fill up quickly with applications from male-identifying participants. To help encourage gender balance, they reserved a given percentage of spaces for girls/non-binary participants. They also ran additional targeted taster days, peer-to-peer meet ups and marketing/promotion materials to engage with girls and non-binary potential participants. These strategies were successful in that they led to the focal programmes achieving a 50:50 balance of male to female/non-binary identifying participants.

## 'Girl and non-binary-only' provision

City North and South spaces also ran some workshops that were only for female and non-binary-identifying young people. Participating girls/non-binary young people, practitioners and parents agreed were valuable for supporting more gender equitable participation in a number of ways. For instance, these groups were described as being more 'comfortable,' 'safe' spaces that supported girls' and non-binary young people's confidence, agency and voice, away from boys, for instance:

> "I would much rather be in an all-girl group." (Girl participant, single-sex workshop, City North).

> "I think because it's girls only they are more likely to sign and up to not be intimidated by it so I am really happy we are doing it." (Youth mentor, City North).

> "So I noticed that now, having a workshop with only girls, it has created a safe space for girls, it creates… it inspires them, it creates motivation for them to pursue whatever they want to pursue. And also, I think the part about the safe space is really important because they can really relax and speak their mind" (Practitioner, City North).

Parents across the spaces, who wanted their daughters/non-binary children to attend, also commented on how the prospect of a space 'without boys' helped make the prospect more appealing, e.g.

> "I think that [workshop] convinced her [daughter] in the end, or maybe I convinced her a little easier because of it. Because it somehow seemed to me, I don't know, that it might be easier for her to connect than it would be if there were only boys there. Because this is also essential, for her to connect with others who are in the course." (Parent, City North).

Despite these successes, gender equity strategies also met with some ambivalence and/or resistance. For instance, one City North parent interviewee recognized that while the workshop had encouraged their daughter to attend, they also worried that it might be "discriminatory" toward boys with similar interests:

> "Yes, I think it's good from this point of view, to encourage them [girls] a little, but at the same time I do not know, well, it can be discriminatory towards some boy who would also want to come to the same thing, But certainly […] it has helped me to encourage her a little and then for her to decide for this." (Parent, City North).

## Engaging with families

Practitioners in the City South makerspaces focused on engaging with families and schools to help understand and address their concerns about the safety, value and viability of girls' participation, in particular. As one practitioner explained: "I will talk with their parents, with their schools to help them. Er, sometimes it's good to invite their parents to see the place and to know us more." In addition to running girl-only workshops, City South spaces also hosted mother and daughter sessions to help build trust, familiarity and understanding. They found that these strategies were highly successful for supporting girls' recruitment and participation. For example, some mothers who came to the family sessions said that they did so in order to find out more about the makerspace and what it offered:

> "I need to know what [City South makerspace] provides to my daughter" (mother, City South).

> "I came to learn more about [City South makerspace]" (mother, City South).

Other mothers felt that being able to come with their daughters helped them to provide an additional level of support and commitment:

> "I wanted to encourage my daughter to come here and in order to let her feel I have her back." (mother, City South).

Hence, all four spaces identified ways in which gender equity had been impeded by previous access and outreach approaches

that had not centered issues of gender equity. All the spaces also found that more girls/young women participated in their programmes when they iterated and employed more gender equitable approaches.

## Steps toward equitable governance

### Diversifying staff and leadership

Practitioners explored ways of diversifying the demographics of their staff, volunteers and peer mentors, ensuring that that their organizations were inclusive and valuing of diverse perspectives and experiences at leadership level. For instance, one of the City South spaces actively prioritized the recruitment of more women staff. A City North space recruited and worked extensively with a non-binary mentor to improve their outreach in this respect. They also invited the youth board chair to sit on the main governance board. By the end of the project, 83% of makerspace practitioners who responded to the endline survey agreed that their makerspaces had increased the diversity of their staff. Each of the makerspaces offered some girl/women/non-binary-only and/or "female-led" sessions and programmes, which proved popular with young women and non-binary youth (e.g., "those grew and grew," CN practitioner pseudonym R).

### Diverse role models and mentors

Both City South and North spaces reflected and evolved their practice in relation to gender role models and mentors. The literature notes the value of female role models and mentors for supporting girls and women's participation in makerspaces (e.g., Eckhardt et al., 2021; Spieler et al., 2020; Richard and Giri, 2017) and each of the spaces already had women staff or facilitators who acted either formally or informally in this capacity. However, the practitioners sought to further extend their practice in several ways. For instance, some spaces took an intersectional approach, recognizing that 'role models' needed to reflect a range of non-dominant demographics and broadening ideas about who constitutes a role model or mentor, to be inclusive of potentially all youth and adults. This approach was experienced as being effective and powerful by participating young people, as one female-identifying participant in a city north makerspace, explained:

> "When joining City North and doing the course, I felt comfortable and did not feel like an outsider. Seeing students who were PoC [people of color] and students who were women, enabled me to have a stronger connection to my cohort. This was especially so as [name- racially minoritised woman] was my first point of contact when joining the course and she was someone I could very much relate to. It was also nice to see students on the course who identified with having a disability as I feel ableist biases often go unnoticed in the tech world."

Some practitioners felt that girls and young women benefitted from being able to meet women who work in STEM fields, but particularly "female role models that contribute to society by working in a field that are usually represented by males." (Mentor/practitioner, City North).

> "In the employment week (which is where we have external speakers) we had 50/50 male to female guests" (practitioner).

Some young men participants also valued the increased diversity of speakers and forms of representation on the courses:

> "I think that the gender split of speakers was majority female which is obviously something that addresses traditional views about who tech is for. [Woman speaker] is someone who has been very successful in the tech scene in [City] which emphasises that gender is not necessarily a barrier to success in tech." (Young man participant).

Young women and non-binary youth in both City South and North spaces felt particularly inspired by role models who matched their gender identity, were from their local communities and who were close to them in age. They particularly valued how peer mentors could share practical insights and were proof that participating in the course in question could result in successful wider outcomes.

> "She [mentor/role model] informed us of what this program is, what it relies on and dates of registration. She also spoke with us about her experience in the final year of school. She made us think from new perspectives, giving us insights on how to choose our majors when enrolling in universities. Moreover, she enlightened us regarding creating our own opportunities in life like travelling for example because I really want to travel." (Young woman, City South).

> "She's [mentor/role model] so ambitious. She has a dream and she's pursuing it now. Despite she has achieved one of her goals, which was finishing her high school being the top of her peers in [country]. She is now planning for her next goals. This is so inspiring, and that's why I consider her as a role model for me." (Young woman, City South).

> "[Name] has showed me her website and I saw like how good it was, I saw how it was like multi page, and how it's very interactive, so [I am] quite keen to like to look at that and see how I could do something similar. And then she'd also, I think [name] had also told me about how she'd been, how she'd got into like her graduate scheme with the [company] and I think that that, that- that that was definitely like one of the things that made me quite keen on this course because I'd seen how, how, how, how successful she had been and I'm- I'm hoping to be like just as successful as her." (Young woman, City North).

Similar views were expressed by other makerspace participants, for instance:

> "I think the [peer] mentors bring a realistic perspective. They are like role models, and they understand my background, like not being privileged growing up and not having many resources. They understand that and can relate to you" (Young woman participant, City North).

As the above quotes suggest, a mentor or role model's capacity to be "realistic" and "relatable" was felt to be more important (for

supporting a sense of belonging and engagement) than being an aspirational figure. We interpret the value offered by such individuals as both social (whereby individuals benefit from a supportive mentor or role model) but also symbolic, where the presence of intersecting forms of diversity among practitioners and participants can help create safe, welcoming spaces where learners can feel a sense of belonging. However, as one City South practitioner also critically reflected, for role models to be part of a gender equity approach, they and other women/girls/non-binary people also need to be included in power-sharing and governance within a makerspace. That is, role model figures need to have a "real say" in the policies, practices and decision-making of an organization and they need to be valued in their own right for their STEM expertise. That is, the value of 'role models' and mentors needs to be realized through lived institutional power relations, as part of a strategy of centering the identities, experiences, knowledges and authority of Others – they should not be tokenistic emblems to just 'inspire' girls/women and non-binary youth to participate.

## Steps toward gender equitable pedagogy

Through critical professional reflection sessions, the practitioners in all four makerspaces came to realize that some of their previous generic, assumed "gender neutral" practices and programmes had unwittingly excluded girls and non-binary youth in particular ways. For instance, some programmes had been implicitly aligned with masculinity due to normative associations of particular STEM disciplines or topics (e.g., engineering, coding, robotics) with masculinity. Others noted that their open registration processes and lack of gender monitoring had led to a predominance of male learners on some of their courses. Some settings recognized that by not asking for and using participants' preferred pronouns, they had unwittingly excluded and/or misgendered trans and non-binary learners. Practitioners worked to apply the overarching gender equity principles (of centering girls/women/non-binary people and attending to gendered language and practices) to their pedagogy in a number of ways, as discussed next.

### Addressing gendered culture, language, representations and practices

Through critical reflection, practitioners paid attention to the culture, language and everyday practices within their spaces, considering the ways in which these were implicitly or explicitly gendered and then, through discussion, identified ways to make these more gender inclusive. As one City North practitioner explained: "we were very mindful not to just create a space that was very male." They evolved their practice by consciously reviewing their use of language and employing more gender inclusive terminology. As one practitioner explained, they no longer regularly referred to participants as "guys" and now routinely welcomed and used participants' preferred pronouns –approaches that were welcomed by young people:

"We also ask people their pronouns and encourage people to add these to their name badges to both normalize this and help prevent misgendering" (City North practitioner).

"Encouraging people to add their pronouns to their name badges normalizes the practice and shows respect for individuals' gender identities. It especially helps create a safer space for transgender and non-binary people and reduces the likelihood of misgendering" (City North, young woman participant).

"Avoiding masculine words and terms that are off-putting to women in promotional materials is a thoughtful approach. It shows an understanding of the potential impact of language on attracting a diverse audience and creates a more inclusive impression of the course" (Young woman participant).

Practitioners also took steps to ensure that their course materials and speaker profiles foregrounded diverse representations of STEM expertise. For instance:

"I chose the topic of women in computing and provided examples of positive role models for the gallery page, examples of the importance of women in tech teams for the index page and a quiz on the impact of a lack of women in tech for the quiz page." (Practitioner).

"Using diverse examples of people in pictures, as speakers and as the course lead, enables students to relate to the individuals better and also imagine themselves in those positions too. It also challenges stereotypes of who would typically be in these positions." (Young woman participant).

### Meeting needs and leveling the playing field

One makerspace was highly mindful of intersectional inequalities, and paid particular attention to creating an environment that support low-income, neurodiverse and racially/religiously minoritized women and non-binary youth:

"We provided refreshments including pastries for breakfast and a hot lunch (because some people might not otherwise eat a hot meal) and we accounted for dietary restrictions including vegetarian, vegan, halal, and allergies. We include regular breaks to ensure people aren't overwhelmed and check in regularly, so we do not move on before everyone is ready.… We also offered support with travel costs for the learners who otherwise would not be able to attend and offered support with childcare." (Practitioner).

### Using asset-based and need-based approaches to support agency

A key development was that practitioners started to re-orientate their pedagogy so that, rather than focusing overwhelmingly on developing participants' STEM knowledge and skills, they also prioritized supporting young people's agency. For instance, a practitioner in a city south space, described how they integrated a focus on supporting girls' agency and voice into a traditional programme that was aimed at developing participants' 'hard' STEM skills (e.g., coding). Rather than seeing the 'soft skills' as supplementary or less important, she described these as "the things that actually matter" and was "really happy" when she could see then she could see how the "small differences" that she made to her practice resulted in girls on the course "talking for themselves" in new ways. For instance, she described the case of one girl on the course, who arrived very shy, and whose parents insisted that her brother escort her each week.

However, over time, the young woman became more confident and, to the practitioner's delight, kept returning each week.

> "The difference I noticed is that the girls talked more than usually do in other workshops where I have to talk to communicate directly with them to get them to engage. In this case they all engaged because they have to, it's all about them. So I think that's the biggest difference, getting them to speak their mind and participate." (Mentor/facilitator, City North).

> "I've joined many different organizations before, but they were only providing us with the content, ignoring our need for a break or entertainment, for example. In the majority of the courses I've attended, the instructors simply provided us with the curriculum and nothing more. They never gave us the floor to present our ideas or laptops that we could use to search for information, unlike [City South makerspace]" (young woman participant, City South).

City South provided another powerful example of how makerspace practitioners redesigned their offers in more gender equitable and inclusive ways to foreground the interests and identities and collective needs of local women and girls and used interdisciplinary, collective, assets-based critical making to support girls/women's agency and social action. Previously, the space had run fairly traditional workshop programmes with young people, that tended to follow familiar 'recipe-book' STEM activities. However, following some equity-based professional development sessions, practitioners became keen to evolve their practice further. Specifically, they wanted to address local concerns about the impact of gendered social and cultural inequalities on women's and girls' participation in STEM and society more generally. They also wanted to use their workshops to address important economic, social and environmental crises and injustices that characterized their local context (e.g., poverty, pollution, energy crisis, safety).

City South practitioners collaborated to develop a mothers and daughters workshop that focused on participants' experiences and visions for a safer, more sustainable and socially just city. They used assets-based approaches, eliciting and valuing participants' knowledge, experiences and views, and thought carefully about how to ensure that the session prioritized supporting participants' agency, voice and social action. The workshop was held off-site, in a local community space and began with a discussion of gender imbalance in STEM. Through discussion, participants were invited to share their own views and experiences, exploring the impact of intersecting inequalities. Participants then shared their experiences as women and girls in their own neighborhoods and talked about the challenges they faced in their daily lives within the city. The group then collaborated to design and model a re-imagined city, with upgraded infrastructure, driven by central concerns of safety (using their designs to address the risks that they experienced as women and girls when navigating spaces), sustainability (considering how to create sustainable, eco-friendly urban spaces and healthy neighborhoods) and social justice (reimagining city design and planning through women's and girls' experiences).

They used recycled materials to create a model that captured their ideas and key design features (e.g., solar-powered lighting, pedestrian hubs). The session was enjoyed by all, and was felt to have valuably supported participants' voice, agency, creativity, enjoyment and engagement with STEM. As participants commented afterwards:

> "I myself enjoyed the workshop, and these kinds of activities help us foster our imagination and STEM-related skills."

> "It is like a space created only for them [daughters] – they can do whatever they like."

> "STEM-related activities help our daughters think in a way more creative in order to create a better future and choose the fields they think are suitable for them."

The practitioners had hoped to carry on extending their ideas and learnings beyond this workshop, working toward longer-term approaches and embedding key insights into their wider practice. However, a couple of months after the workshop their lives were fundamentally, catastrophically changed by war, resulting in the destruction of the makerspace and the deaths and/or displacement of practitioners and participants – a situation that remained ongoing at the time of writing.

## Hurdles and blocks to progress: 'sticky' inequalities and the slow pace of change

Despite evolving and progressing their practice in a number of ways, practitioners also recognized a number of various barriers and limitations to their efforts to progress gender equity in their spaces and programmes, as discussed next.

### Masculine resistance to gender equity work

Despite all-staff professional development workshops, some male staff admitted that they found it difficult to give up old habits and to make change "stick," as one termed it, in their practice. One City North practitioner also reflected that while he was now more aware of gender inequalities, this had not yet led to action:

> "We … certainly let boys talk more than girls. It's not something we are proactive about. We need to address this." (Practitioner, man).

Observation notes from youth programmes that were conducted after the professional development training also reinforced this point. For instance, observers recorded examples of male practitioners using very similar forms of practice to those espoused at the start of the project, such as adopting a 'teacher-like' role, authoritatively explaining topics from the front, using 'recipe-style' approaches and showing little awareness of gendered dynamics.

> "The lead practitioner (who identifies as white male) leads the session. He begins by talking through a PowerPoint presentation on the importance of and science behind solar chargers. He stands at the front of the class and then invites questions using a 'hands up' Q&A approach, which he answers with factual responses, reflecting his STEM knowledge and expertise. He then explains the task and hands out kits and instruction sheets. The class work through the activity individually at their own pace. Girls tend to

be quiet. They make their own solar chargers by themselves following the step-by-step instructions. Boys are more active and talkative with each other and ask more questions. They make more (successful) bids to gain the mentors' attention." (Observation notes, after-school weekly youth workshop).

Hence although the adapted recruitment strategies resulted in equal numbers of boys and girls in the session, there were few discernible changes to the pedagogy of this session to make it more gender equitable and inclusive. The same issue was also noted in some single-sex workshops led by women facilitators, indicating how merely ensuring that sessions contain only or predominantly female staff and participants does not automatically result in gender equitable pedagogy.

Practitioners recounted how despite their good intentions, particular gender equity efforts had not always worked out, such as attempts to bring in diverse STEM experts:

"We tried hard to include carefully planned and diverse representation in our guest speakers. Unfortunately, a number of people dropped-out at the last minute – including two former learners, and two industry professionals – all diverse/female" (City North, practitioner).

Some women practitioners shared their frustration with the slow pace of change within their settings and felt that gender equity was not always taken up as a priority by male colleagues. For instance, a City South practitioner described the ongoing challenges that she faced when trying to get male colleagues to understand how and why they need to adapt their practice and share responsibility for creating a conducive environment for girls' active participation – rather than this just being her job. As she lamented, many seemed to be "just not aware" of the issues either for girls or for female staff. She felt that some ideas did not seem to 'stick' with these colleagues, such as their continued assumption that girls' tendency to be quieter in sessions, compared with their male peers, and their comparative reluctance to offer ideas or participate in class debates was their 'choice,' not appreciating the ways in which women/girls can be silenced within masculine-dominated contexts.

Young people also identified how gender equity work needs to focus more on changing the sexist behaviors of boys/men. As one put it:

"It's not only a problem of how girls perceive themselves in society, but of course also how the boys are brought up about this situation […]. So I do not know what can be the solution, but I think that also guys should have some education about this problem and how to tackle it as a male. I mean how to not interrupt girls, how to not feed them with insecurities and how also female scientists exist and we have a lot of genders there that are not represented, in the media and also in schools as much as the male scientists." (City North, young woman mentor).

This issue is not particular to makerspaces and the wider literature draws attention to how gender diversity work often meets with resistance (at both individual and institutional levels) within organizations and workplaces, leading to a slow pace and/or lack of change. For instance, Ahmed (2012) identifies and discusses the

"paradox between, on the one hand, the ubiquitous use of diversity as an official language by institutions and, on the other, how practitioners experience those institutions as resistant to their work" (p. 17). Studies chart the different ways in which men, in particular, resist workplace gender equity initiatives (e.g., Wahl, 2010; Hearn, 2001; Jones et al., 2021) and it has been argued that more research is needed to understand the different forms of resistance to gender equity training at individual and institutional levels (e.g., Lombardo and Mergaert, 2016).

## Little change in physical spaces

Toward the start of the project, professional development sessions conducted with makerspace practitioners had highlighted the gendered construction of physical and social space within makerspaces and had explored ways that spaces might better welcome and represent gender diverse STEM expertise and identities (e.g., Keune and Peppler, 2019) through, for instance, wall displays, furniture choices, photographs, artworks and displays of works in progress (e.g., Calabrese Barton et al., 2021). However, over the course of the project, field notes did not record any subsequent substantive changes in the participating makerspaces' physical settings – although one space did change the set-up of tables within youth workshops, moving them from a didactic arrangement (all facing the board/facilitator at the front) to a more informal, group-work arrangement, designed to facilitate small group discussion/working and to help the practitioner to adopt less of a 'teacher' role. However, in most spaces, no changes were noted. As an observation of one practitioner's workshop session recorded:

"Although the gendering of spaces was discussed over six months ago at a previous professional development meeting and ideas were suggested, no changes have been made to the physical room (e.g. to make it more representative and welcoming to girls and non-binary youth) – it is still very much a 'technical' space, full of equipment, machinery and materials with no representations of young people or community" (Field notes, site visit spring 2023).

## Gendered societal roles, behaviors and expectations

Some practitioners noted that wider societal relations and issues also made progress difficult. As a City South practitioner reflected in her final interview: "it's always been a challenge, right?," referring to the difficulties she continued to face both personally and professionally, as the only woman member of staff and living and working what she termed a gender-traditional society. She felt that beyond the makerspaces, progress toward gender equity in STEM was hindered due to a lack of allyship with women who had succeed in the STEM industry, who tended to "keep their heads down" and "ignore" gender inequity issues in their disciplines. Within her space, she shared how in meetings, some male colleagues did not address her directly but rather talked over her, addressing other men. She was also painfully aware that, as a woman, her credibility as a STEM professional was always in question and required careful physical and social management ("Oh my God, as a female we need to be so careful how we dress"). She recounted an example of a meeting with education policy officials, where she felt compelled to make careful, deliberate choices to ensure her clothing met particular gender and cultural expectations in order to be seen as "convincing," whereas her male

colleague was taken seriously despite wearing casual shorts and T-shirt. While she had attempted to challenge such behaviors ("Its been years that I've been working on it"), without any allies, she felt her efforts were limited, leaving her unsupported and alone.

## The value of space and support to engage with gender equity

Practitioners in all the spaces felt that participating in the research project had provided a valuable forum to discuss the issues and share experiences. Women practitioners in particular were more likely to describe their experiences in the project as "transformatory" and "amazing" – whereas men practitioners were positive but more circumspect (e.g., as describing participation as having "enriched" their knowledge and practice; naming what they had "learned"). As a City South practitioner explained, she valued "being able to express what's happening to me" and draw attention to the "ongoing challenge for females" in makerspaces in her country. While she was heartened by some of the progress achieved ("it is shifting") she believed that "a bit of catalyst is still required … people say things are changing but then deep down it still needs a lot of pushing."

## Discussion and conclusion

The existing literature usefully details the ways in which the dominant masculine gendering of makerspaces (physically, socially and symbolically) contributes to the persistent exclusion and marginalization of women/girls and non-binary youth within makerspaces. While, to date, studies have predominantly tended to focus on understanding the experiences, identities and motivations of adult women participants in Global North makerspaces, this paper has sought to examine the affordances and limitations experienced by makerspace educators (in Global North and South settings) when trying to enact and advance gender equity within their spaces in order to better support the engagement and participation of girls and non-binary youth in STEM.

In line with existing literature, practitioners and young people recounted ways in which the association of STEM with masculinity (and the practices associated with this) and forms of sexism were common barriers to gender equity. However, in line with existing literature, and as detailed in Table 2, they also took a number of steps toward more gender equitable practice in relation to access/outreach, governance and pedagogy.

In line with the existing literature (e.g., Hedditch and Vyas, 2021, p. 12), the findings underlined the value of supporting staff to understand and address gendered language and stereotyping within their settings. For instance, changing the gendered language of recruitment and marketing materials was found to support more inclusive participation. The findings also echo existing literature on the value of equity-focused professional development and support for critical reflection (e.g., Eckhardt et al., 2021; Shinnick, 2019) – but they also provide additional new insights into how such work can meet with resistance and challenges, particularly from some male staff.

The findings echo existing research that shows how supporting agency and social action among girls and non-binary youth through STEM-rich making is a powerful form of inclusive practice (e.g., Calabrese Barton and Tan, 2010; Foster, 2019; Vossoughi et al., 2016). This study offers further concrete insights into how this can be enacted

through access/outreach, governance and pedagogy and also highlights how foregrounding respect for pronouns and the use of female and non-binary identifying sessions and programmes can also support more gender equitable participation in makerspaces.

In terms of centering girls/women and non-binary youth within makerspace practice, the findings reinforce existing literature on which shows the value of using forms of making and crafting to disrupt gendered binaries between STEM and creativity (Richard and Giri, 2017), broaden dominant notions of STEM and engage with topics such as feminism, gender, sexuality, and society (Rogers, 2017) using assets-based pedagogical approaches (Keune and Peppler, 2019). Our study also offers some practical insights into how outreach practices might be tailored to safeguard the participation of girls and non-binary youth. The findings also support existing work on the use of gender representation and diverse role models and mentors within makerspaces (e.g., Spieler et al., 2020; Eckhardt et al., 2021; Dayton, 2017) and extend these in relation to governance and pedagogy. In particular, analyses draw attention to the importance of intersectionality, the value of local, community (not just professional/aspirational) role models, the value of taking a considered approach to the use of gendered language and pronouns and the value of single sex offers. Additionally, analyses considered the resistances that practitioners experienced when trying to enact gender equity in their settings.

Finally, the present study offered some new insights into the value of supporting capital (social and cultural resources) among girls/non-binary youth, their families and the wider community as part of gender equity work. For instance, outreach taster days can help to build young people's familiarity and understanding (cultural capital) and relationships (social capital) to support access and participation. Meeting the needs of participants (e.g., through food, transport, breaks, access to equipment) was also valuable for supporting engagement, retention and participation.

Comparing data from global north and south settings, we are reminded that gender inequity plays out in both similar and different ways across time and context. From this, we extrapolate that while top-level common principles are helpful, gender equity approaches also need to be locally grounded and attuned to place-based specificities. We note that more attention might usefully be given to addressing sexist thinking and behaviors among boys/men in makerspaces and to extending understanding of how to address some male educators' resistance to gender equity strategies. We interpret the issue of male resistance to gender equity approaches as illustrating the 'sticky' nature of gender injustice – in which gender inequity and male dominance represents the status quo (it is not special, rare or unusual) and hence attempts to challenge and change this will inevitably be difficult and meet resistance.

## Implications for practice

We interpret our data as offering various implications for practice, including the importance of shifting professional discourse and interventions away from 'changing' girls/non-binary youth and toward 'changing practice.' Rather than seeking to change young people's attitudes or support their resilience within gender inequitable settings, we suggest that greater emphasis could usefully be placed on supporting critical reflection on gender among educators and on

supporting more equitable practice and more gender inclusive spaces and cultures. Our findings also support more critical engagement with the concept of role models, calling for these to be considered intersectionally, through lenses of power and governance.

We suggest that embedding gender equity within STEM learning spaces requires that issues of equity become 'everyone's business' – not just the role or preserve of particular dedicated individuals. We also agree that youth programmes need to be driven by purposeful, socially and culturally sensitive making that supports all young people's agency, but particularly those from under-represented communities (Vossoughi et al., 2016). We see investment in critical professional reflection as a valuable driver for change in this respect – although this remains relatively rare still within the makerspace sector globally. As noted by Nag Chowdhuri and Archer (2023), embedding critical professional reflection within STEM learning settings will require the requisite time, scaffolding and resource to enable practitioners (but particularly men practitioners) to embrace discomfort to recognize and productively engage with their own privilege. As recognized by both educators and young people in our study, equity work is never finished but is part of an ongoing, evolving journey, that needs to be urgently embraced, resourced and supported.

In order to support gender equitable practice in makerspaces, practitioners and leaders may wish to use resources produced by the Making Spaces project[2] which are designed specifically to support equitable practice within makerspaces. The resources include a comprehensive digital guide (that sets out key principles, evidence, case studies and practical exercises), a free online, self-paced short professional development course for makerspace practitioners and a range of tools, such as the Equity Barometer, that help capture the extent to which young people are experiencing a given makerspace or programme as equitable and inclusive. The data afforded by these tools can help provide leaders and practitioners with insights into areas for further development and can help makerspaces to capture and chart their progress toward greater gender equity and inclusion.

## Limitations and future steps

The limited sample and data discussed in this paper mean that we cannot generalize the findings to wider makerspace settings. We are particularly aware of the limited data and discussion afforded to non-binary and trans young people within this paper, due to a paucity of data and the imperative to protect the anonymity of participants. We recognize that the participating practitioners and their institutional settings are all still progressing their respective gender equity journeys – they, and we, are aware that there are always further steps to take. We recognize that the different locations, demographics, relations and circumstances of the makerspaces mean that they each have different resources, starting points and levels of risk associated with being able to engage in and undertake gender equity work in their settings. Our consideration of the steps that they have taken to date is not held up as any sort of gold standard or idealized representation of gender equity work. Rather, we hope that the accounts of their experiences and challenges

can help provide useful insights and learning points for others embarking upon and/or supporting gender equity work across informal STEM learning settings, such as makerspaces. We hope that the findings may also be useful for informing policy – in particular we call for a shift in focus, moving beyond the existing emphasis on trying to 'encourage' girls/women and non-binary youth into STEM spaces, to focus instead on changing the dominant (masculinist) cultures and practices within these spaces that produce and sustain gendered (and other intersectional) patterns of participation.

## Data availability statement

The datasets presented in this article are not readily available because the qualitative data is not able to be shared due to highly identifiable data that would compromise anonymity and confidentiality of participants. Requests to access the datasets should be directed to l.archer@ucl.ac.uk.

## Ethics statement

The studies involving humans were approved by the Research Ethics Committee, University College London. The studies were conducted in accordance with the local legislation and institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin.

## Author contributions

LA: Conceptualization, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Writing – original draft, Writing – review & editing. EF: Writing – review & editing. MN: Writing – review & editing. JD: Writing – review & editing. QL: Writing – review & editing. FG: Writing – review & editing.

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## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

## Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

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