Owning Her Story: Exploring Attitudes towards Gender Diversity in STEM through Augmented Reality Fictions

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Fig. 1. Participants crafting their stories in the workshop.

This study explores diversity initiatives in STEM, focusing on gender-based discrimination. Four archetypes of attitudes, Doubtful Advocate, Cautious Observer, Quiet Achiever, and Empowered Activist are identified through co-design workshops using comic-based augmented reality (AR) design fiction and interviews with 12 STEM Higher Education students. The exploratory study provides insights for designing AR platforms that support diversity in STEM and contribute to diversity initiatives through a Feminist HCI lens by enabling users to share experiences, brainstorm solutions, and practice responses to discrimination.

CCS Concepts: • **Human-centered computing** → **Mixed / augmented reality**; **HCI design and evaluation methods**.

Additional Key Words and Phrases: co-design, feminist HCI, empathy machine, STEM

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1 INTRODUCTION

This study examines the difference in the number of men and women in Science, Technology, Engineering, and Math (STEM). This gap affects how many female students are recruited by colleges and universities and how many stay in STEM jobs after graduation. When women leave these fields, we lose a lot of knowledge, experience, talent, skill, and perspective. This significantly affects the women, their families, and society (e.g., [42]). To explore this issue, we engaged 12 STEM higher education students who responded to our recruitment emails and expressed interest in contributing to

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diversity in STEM. We conducted two iterations Identity Workshop that we piloted before [32]. This workshop format utilised comic-based augmented reality prototyping and semi-structured interviews.

Our research questions are as follows:

- **RQ1.** How do students in STEM Higher Education perceive and experience gender diversity within their fields?
- **RQ2.** How do students in STEM Higher Education envision using augmented reality as a medium for supporting gender diversity initiatives?

Our data analysis developed the *STEM student archetypes*. This categorises participant attitudes towards discrimination into four archetypes: Doubtful Advocate, Cautious Observer, Quiet Achiever, and Empowered Activist. This set of archetypes could serve as a starting point for designing tailored research and programs. The findings from the workshops and interviews revealed insights into the participants' experiences and positions regarding organisational diversity issues. Augmented reality-based storytelling can be an asset for diversity and inclusion aims in an organisation, especially if deployed as a collaborative tool to support the co-creation of narratives of empowerment and a safer exploration of sensitive scenarios.

The experiences and perceptions of gender diversity in STEM, as revealed by our participants, align with the broader discourse on the masculine culture of technology [15, 51]. AR as a medium for supporting diversity initiatives also builds upon the existing work on immersive technologies as empathy machines in diversity, equity, and inclusion (e.g. [28, 31, 32]). The design implications derived from our study offer practical ways to address the challenges identified in the background, such as the underrepresentation of women in STEM and the identified need for more inclusive cultures that value diversity and different backgrounds [42].

2 BACKGROUND

2.1 Diversity in STEM: A Focus on Gender

"Diversity" is a multifaceted concept encompassing various identity intersections [17]. Our study focuses on gender-based discrimination within STEM fields. Gender, a social construct, permeates numerous life aspects [51]. STEM disciplines impact everyone's life - for example, as Breslin (2018) points out, the lack of women and ethnic minorities in tech positions at prominent Silicon Valley companies like Google, Facebook, and Twitter, where 80-90% of tech positions are filled by men, is not due to biological differences in ability [15]. This disparity is often associated with a symbolic coding of STEM, and primarily technological, careers as masculine, which cyclically works to reinforce stereotypes about women's abilities [15]. Nevertheless, the practitioners and designers in these fields fail to reflect the diverse population they influence. In Australia, STEM-related fields are predominantly male [36, 42]. As Cech (2022) found, white non-disabled heterosexual men experience more social inclusion, professional respect, and career opportunities and have higher salaries and persistent intentions than STEM professionals in 31 other intersectional groups [17]. Although research indicates that gender-diverse team outperform their gender-uniform counterparts [9, 26], merely "adding diversity and stirring" is insufficient [26]: it is crucial to cultivate a community culture that values diversity and varied backgrounds [26, 41].

Women's sense of alienation in STEM fields can be attributed to phenomena like stereotype threat and imposter syndrome. "Stereotype threat" is a psychological concept identified as contributing to women's underperformance and underrepresentation in mathematics and science disciplines [47]. Collins describes a psychological condition prevalent among individuals who are the sole representatives of their gender, race or the youngest in advanced STEM classes. Despite their significant skills, these individuals often feel like outsiders within and outside the classroom. They may

even downplay their talents to fit in. This syndrome can lead to a sense of living a double life, particularly for women of colour, who may feel they do not truly belong to either of their identities [23]. Related to this, "Imposter phenomena" or "imposter syndrome", as defined by Clance & Imes in 1978, is a psychological state where individuals, despite their significant achievements, persistently view themselves as intellectual frauds [19]. Bias and stereotypes play a significant role in the underrepresentation of women in STEM fields [44, 45]. Implicit biases, often unconscious and ingrained, can influence decision-making processes, perpetuating gender disparities and hindering the progress of women in STEM [39]. These biases can manifest in various forms, such as stereotype threat, and contribute to phenomena like imposter syndrome [44]. Therefore, aiming to create an inclusive culture in STEM requires conscious efforts to address these biases [39, 45]. Addressing gender diversity in STEM is a multifaceted issue that requires innovative approaches.

2.2 Immersive Technologies as Empathy Machines in Diversity, Equity, and Inclusion

Immersive technologies like Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR) are one innovative approach that has been used in research to address gender diversity (e.g. [46]). Using immersive technologies can give visceral glimpses into what it is to be another, and embodying virtual characters has been shown to create a sense of presence [2] and a change in perspective [31]. Studies have shown that these experiences can lead to improved understanding [30, 35], reduced bias [33, 47], and encouraged pro-social behaviour [28].

These technologies, sometimes called 'empathy machines', can facilitate perspective-taking [37], a key component in designing diversity initiatives. The term 'empathy machine' was initially coined by film critic Roger Ebert to describe movies [48] and then further popularized to describe immersive virtual experiences by Chris Milk [40]. Empathy is often understood in creating immersive experiences as the ability to "step into someone's shoes" [49]. However, empathy is a complex concept that can be understood in many ways. For this research, we use Wiseman's attributes of empathy to define it. Wiseman's four defining attributes of empathy [60] are the following:

(1) to be able to see the world as others see it.
(2) to be nonjudgmental
(3) to understand another person's feelings
(4) to communicate your understanding of one's feelings

In the context of this framework, most of the described "empathy machines" focus mainly on the first attribute: "to be able to see the world as others see it." However, the other attributes must also be considered to address ethical concerns and design for practical empathy. Based on this definition, empathy can never be one-directional. Feeling empathy is experiencing the emotions of the person or people one empathises with and shares some level of common humanity. To gain this understanding, the person must connect the experience to themselves and their own experiences. Empathy requires understanding their position and reflection on themselves. Studies show that the ability and level of experienced empathy are related to the user's personality and experiences [55]. In other words, empathy, like many other human experiences, is not universally applicable. Another aspect is "communicating one's understanding of that person's feelings." Suppose the advertised empathy, the understanding of the target's feelings, which are usually painful and vulnerable, via virtually "walking in their shoes", is never communicated back to the target. In that case, it is robbing them of the opportunity to either confirm or decline the level of accuracy of this understanding.

Other challenges exist. For instance, Lopez et al. found that participants embodied in female avatars displayed higher levels of implicit gender bias than those in male avatars [38]. Other challenges include motion sickness, the underrepresentation of women as both participants and authors in VR research [46], and the potential for AR and

VR technologies to perpetuate discrimination, including gender discrimination [1]. Some studies have shown that online perspective-taking did not reveal a significant influence of avatar gender on candidate ratings or choice [24]. In contrast, virtual reality perspective-taking significantly changed participant behaviour following exposure to a gender-incongruent avatar [24].

Despite these challenges, research has shown that immersive experiences can improve learning by making learners more interested and motivated [50]. We chose to study AR in this context, as it maintains the context of the natural world [56] while exploring these virtual narratives, aligning with Barzell's Feminist HCI qualities [7]. To avoid toxic empathy or unethical nudging, a responsible design of perspective-taking technology should be transparent about its positionality in terms of who designed the tool based on what values and for what aims, and the people to be empathized with should also be included in the design and creation process for mutual benefit.

2.3 Augmented Reality and Storytelling

Augmented Reality, an immersive experience, can elicit a strong sense of presence and understanding of different perspectives. It overlays digital information onto the physical world, creating a contextually integrated and semantically consistent experience [5]. AR's potential lies in its ability to locate narratives in real places, making stories of diversity in STEM visible [56]. As Azuma [6] notes, storytelling is fundamentally important, and advancements in media technology that enable more compelling storytelling can have a profound impact. AR's innate quality of tying virtual elements to real present locations and times connects virtual characters to real people and settings [32]. Similarly, Calvi [16] defines AR storytelling as the use of augmented reality to create narratives that enhance user engagement and experience by integrating virtual elements with real-world contexts. This connection can lead to a sense of agency, inspiring individuals to take action and drive change [18, 29].

Storytelling is vital to exploring possible alternative futures [12]. It is well-recognized in design research that novel designs and technologies are always understood in the context of a narrative [3, 25]. Shin and colleagues [56], in their recent systematic review, analysed 64 articles on AR storytelling. They concluded, "that the design of augmented narrative space is fundamentally shaped by how connections between the virtual and the real define, support, and leverage the degree of dominance of one spatial entity over the other." [56]. Therefore, understanding and strategically designing these connections is crucial for creating immersive and compelling AR experiences. Our research seeks to extend these ideas to imagining and telling stories about a different STEM culture or workplace.

2.4 Feminist HCI

Feminist HCI is a lens to understand and address gender disparities in STEM, not due to biological differences in abilities, but often associated with the symbolic coding of technology and technological careers as masculine [15, 27]. This coding reinforces stereotypes about women's abilities, leading to a decline in women's performance due to the perception of being judged according to these stereotypes. It also leads to differentials regarding access, support, and opportunity for women in using and designing technologies [15].

The lack of diversity in STEM and HCI is problematic due to the common practice of designers and developers using themselves as model users, referred to as the "I-methodology" [43]. Most developers are typically well-educated, middle-class, white males, and as a result, they often replicate the norms and values of this group [15, 43]. Studies show that gender-diverse teams with supportive infrastructures and cultures perform better than gender-uniform teams [9], possibly because they bring a wide range of ideas to the design and construction of technologies [15].

Feminist HCI is a method for creating more inclusive designs and practices. Several frameworks have been proposed as approaches to doing feminist design [7, 10, 51, 58]. Bardzell's approach rests on feminist standpoint theory, suggesting that attention to multiple standpoints can work as a way to incorporate "marginal" users as part of the design process. She points to several qualities that should be used as a constellation for a feminist approach to interaction design: pluralism, participation, advocacy, ecology, self-disclosure, and embodiment [8]. Her discussion provides a general overview of what a feminist HCI could look like [7]. Rode takes this as a basis and works to provide a sociotechnical theory for gender and HCI based on three approaches: technology as masculine culture, gender positionality, and lived body experience [51].

3 METHODOLOGY

Our chosen research approaches are research through design [61] and feminist HCI [8]. We held two co-design workshops where participants created paper-based augmented reality fiction in comic format. We chose this method as a basis for our fiction as comic-based storytelling for self-expression has been explored as an effective method before, for example, by Rutta et al. [53]. We also conducted 45-minute interviews to let participants share their thoughts privately and collected demographic information through a short survey. We synthesized the findings from the workshops and interviews to develop our recommendations and present the co-design workshop method. We used Braun and Clarke's thematic analysis [21] for analysis purposes. Thematic analysis is an iterative process of identifying, analyzing, and reporting themes from the data. This iterative process is described in more detail in section 3.6. Our institution's ethics committee approved this methodology.

3.1 Research Approach

We aim to produce artifacts, as described by Zimmerman et al.: "outcomes that can transform the world from its current state to a preferred state," focused on contributing to knowledge [61]. We loosely apply co-design fiction as described by Ambe et al. [3] as an approach to "envision and speculate not just on future technology but future life through co-created fictional works." This approach is, in turn, based on Blythe's discussion of design fictions [12]. We further directly build on and develop the co-design workshop, Identity Workshop, a method developed by Holopainen et al. [32].

In this research, we apply the principles of Feminist HCI, as outlined by Bardzell [7] and Rode [51], to our research design. The examples provided below illustrate how we have incorporated the qualities of pluralism, participation, advocacy, ecology, embodiment, and self-disclosure into our methodology:

- **Pluralism**: We incorporate the quality of pluralism by challenging the accepted norms of STEM. We explore alternative approaches and recognize that our designs are specific to the time, place, and community they were created, acknowledging that they may not be universally applicable.
- **Participation**: We ensure participation by actively involving higher education students who have experienced marginalization due to their gender or cultural background in the co-design process. We view our research participants as stakeholders and strive to empower them to contribute to solving community problems.
- **Advocacy**: Our research is rooted in advocacy. We are committed to advocating for ethical representation and the inclusion of marginalized voices in STEM fields, with a specific focus on improving the position of women in STEM.

Table 1. Participants

Code	Workshop	Interviewed?	Gender	Age Group	Background	Field
P1	WS1	Yes	Woman	25 - 34	Asian/New Zealand	Computer Science
P2	WS1	Yes	Woman	25 - 34	Asian	Computer Science
P3	WS1	Yes	Man	25 - 34	Asian	Computer Science
P4	WS1	Yes	Woman	25 - 34	English, South Asian	Computer Science
P5	WS1	Yes	Woman	18 - 24	Prefer not to say	Engineering
P6	WS1	Yes	Woman	25 - 34	Asian	Business (Considered CS)
P7	-	Yes	Woman	25 - 34	Asian	Computer Science
P8	-	Yes	Woman	34 - 44	European	Information Technology
P9	WS2	Yes	Woman	25 - 34	European	Computer Science
P10	WS2	Yes	Woman	25 - 34	Australian/European	Computer Science
P11	WS2	No	Man	25 - 34	Asian	Computer Science
P12	WS2	Yes	Man	25 - 34	Prefer not to say	Computer Science

- **Ecology**: We acknowledge the broader context in which our designs will be used. We aim to contribute to the conversation about the ethics of developing empathy machines and their impact on minoritized communities. We also strive to influence the design of these tools towards a reflective and responsible direction, embodying the quality of ecology.
- **Embodiment**: We incorporate embodiment by designing for whole-body interactions. We consider the participant's emotions as an important guide for design, ensuring that our designs cater to the holistic experience of the users.
- **Self-disclosure**: We empower participants to define themselves in the study context. We provide options in the intake survey and encourage self-reflection in both the workshops and the interviews, allowing for self-disclosure and personal expression within the research process.

3.2 Participants and Recruitment

In line with Bardzell's Feminist HCI qualities of self-disclosure, plurality, and participation [7], we recruited anyone over 18 years old interested in contributing to diversity in STEM higher education. We used an online intake survey to understand our participants' demographics. The study attracted 12 participants: three men and nine women. Most interested individuals were women aged between 18 and 44 in Computer Science, leading us to focus on women's experiences in STEM, especially in technological fields. Participants could join a 3-hour workshop, a 45-minute interview, or both. Ten participants attended one of two workshops, and nine participated in an interview. See Table 1 for more details.

3.3 Identity Workshop

The 'Identity Workshop' method, as explained in our previous publication [32], enables structured exploration of identities. This method aims to deconstruct and reconstruct identities through iterative phases. This feminist HCI-rooted co-design method promotes open engagement, amplifies marginalised voices, and challenges power dynamics for equitable design. Trust, crucial for productive workshops [20], is built through formal and informal interactions and artifact co-creation. Addressing diversity can risk backlash [34, 54], but managed conflict can drive change [52]. The Identity Workshop, a safe space for discussing STEM diversity, balances individual and group activities for reflection and

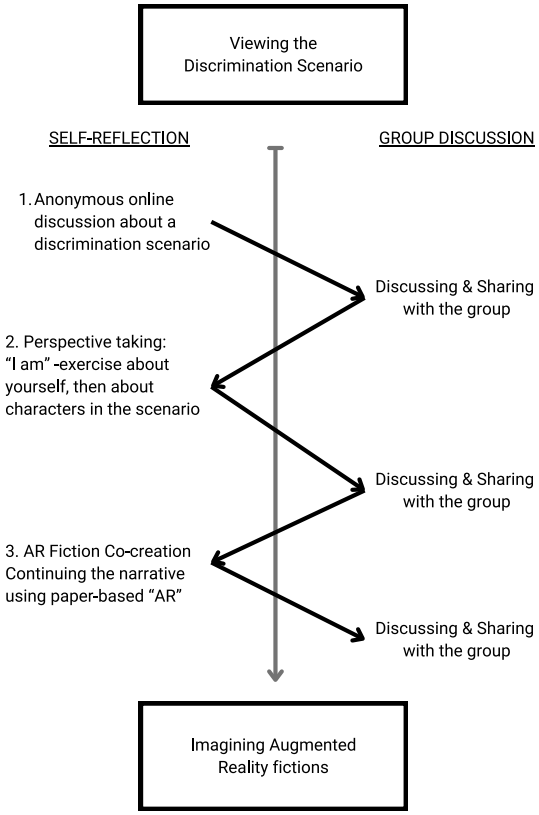

Fig. 2. The co-design workshop flow

creativity. Participants use comic-based prototyping [32, 53] to experiment with diverse scenarios, creating narratives that contribute to transformational knowledge [4, 52].

We held two iterations of this workshops and had 12 participants in total. We held these workshops in a university classroom, offering food, refreshments, and a small reimbursement. Each 3-hour workshop had three sections: an anonymous online discussion about a discrimination scenario, a perspective-taking activity, and a co-creation activity for crafting paper-based AR fiction. Before the workshop, participants examined an online prototype and participated in an anonymous online discussion. The prototype displayed low-fidelity AR designs of gender-based discrimination incidents on a university campus. Each section started with an individual self-reflective element and was followed by a group discussion as detailed in Figure 2.

The workshops began with an introduction to the study and its aims. Participants who still needed to complete the pre-workshop activities viewed the online prototype and answered online questions. We then started a group discussion of the anonymous answers. Participants completed an “I am _” exercise [57], adding as many descriptors about themselves in 60 seconds as possible. This exercise was expanded to include all characters in the prototype scenarios. Finally, participants crafted paper-based AR scenarios to continue the story in the online prototype.

3.4 Semi-structured Interviews

Semi-structured interviews [11] were used to understand workshop participants' views on STEM diversity, their actions, and experiences that could inform diversity training design. We conducted nine interviews, each lasting approximately 45 minutes. The interview plan, included in Appendix A, was prepared to ensure straightforward, concise questions and a logical topic order. This approach, common in qualitative HCI research [11], allowed for flexibility and the pursuit of unexpected topics, providing rich qualitative data for our study. In exploring future design possibilities, we presented detailed scenarios of use for critique, grounding the situation for participants and enriching our data.

3.5 Data Analysis

The qualitative nature of this study yielded a rich collection of transcripts from interviews and workshops. We followed the 6 phases of Braun & Clarke's Thematic analysis [13]. All the workshops and interviews were audio, video recorded, and transcribed using the AI service Otter.ai. The transcripts were then refined for clarity and accuracy. In addition to video recordings, participant observations were documented throughout the research. The cleaned transcripts were uploaded to NVivo in PDF format, marking the commencement of the preliminary annotation and coding process. This process involved multiple reviews of the material to ensure familiarity with the data. By analysing the workshops and interviews, I identified codes related to belonging and culture in STEM fields, including belonging, influence, in/security, and support. Based on the initial codes, themes were generated through my reflective engagement with the data and analytic process. Relevant passages were then moved to Miro, a virtual whiteboard, for collaborative analysis with co-authors. Themes were looked at from the interview data, the workshop discussion, and the comic-based storyboards from the AR design fiction. Throughout the analysis process, these themes were iteratively reviewed, what Braun and Clarke call shared meaning brought together by a core concept [14]. Some of the themes were combined, changed, or removed. There were also iterative discussions and a look back at the research questions. We finally defined and named the themes against different dimensions. Defining the themes formed the basis for the belonging/activism matrix (See Figure 4) and the four archetypes of attitudes.

4 FINDINGS

Our analysis of the workshops and interviews identified themes related to belonging and culture in STEM fields, including belonging, influence, in/security, and support. Relevant passages were then moved to Miro, a virtual whiteboard, for collaborative analysis with co-authors. We initially selected quotes from each theme and assigned colours to them: blue for depressed or defeated comments, red for angry or frustrated, green for optimistic and happy, and yellow for neutral. At the same time, we identified interesting recurring topics, such as passages referring to family influence.

We organized the data into different dimensions based on the key themes identified, iterative discussions, and a review of the research questions. Our goal was to explore the relationships between the different themes and the attitudes expressed by participants in each category.

4.1 Experiences of discrimination

4.1.1 Internal/External; Individual/Collective. Through the data analysis and discussion, we first identified two key dimensions that helped organize and make sense of the collected data.

The first dimension includes quotes or episodes taking an internal versus an external perspective (e.g., episodes or comments relating to oneself or one's group, as opposed to comments relating to someone else). The second dimension

includes quotes taking an individual versus a collective perspective (e.g., comments relating to a specific person, either the participant themselves or someone else, as opposed to comments relating to a group, whether the participant is or is not a member of that group). Below are example quotes from each group.

- **Internal/individual (Me):** *… and I am not just a diversity hire, I have something to bring…*
- **Internal/Group (Us):** *… we may not feel comfortable speaking up…*
- **External/Individual (Someone):** *… if no one speaks up about it, it will happen to someone else…*
- **External/Group (Others):** *You know, there's a whole tradie* [1] *culture there as well…*

See more outstanding quotes in Table 3. We aimed to explore the relationships between the different themes and the emotions and attitudes expressed by the participants in each category. We found that most optimistic sentiments were in the collective/internal "us" category.

4.1.2 Tensions and Frustrations. Many participants expressed tension, frustration, and discomfort with diversity initiatives. During the discussions, many participants expressed feelings of tension and frustration. Some even shared their self-doubt and feelings of inferiority. We interpret these comments as signs of imposter syndrome. While some people believed that quotas and other initiatives to level the playing field were necessary, others felt uncomfortable with the idea of receiving an edge solely because of their gender. On one hand, some participants expressed resentment towards receiving special treatment despite working equally as much or even more than their peers. On the other hand, some participants felt pressured to work harder to prove they belonged. Despite support systems, some participants needed to know their rights within the university culture. One participant shared their friend's experience of facing racism from their supervisor but not knowing how to seek help until the final year of their PhD:

> *"One of my friends was having issues with her supervisor; he was racist towards her. So, she eventually contacted higher degree research student support, and they helped her a lot. However, she waited until her last year of [the] PhD because she didn't know."*

Occurrences like this were causing discomfort and frustration among the participants. Some participants were afraid to speak up about their experiences of discrimination for fear of losing opportunities, and others expressed anxiety about becoming a target.

4.2 Hopes and Reframing

Several participants expressed hope in the current situation and shared their views on reframing the issues. They emphasized the importance of finding their group's allies, mentors, and sponsors. For instance, one participant shared how a professor's comment during a reading group helped them shift their perception about being a diversity hire: *"I was feeling like that I was just a diversity hire, and then a professor not even knowing it just in a reading group one week talking about how diversity brings so much the workplace that totally shifted how I was thinking about my situation."*

Moreover, participants suggested that diversity should be viewed as a desirable and valuable asset rather than an unfair advantage. They highlighted the importance of celebrating diversity and recognizing individuals' unique perspectives in the workplace. Participants hoped for STEM cultures to open up to diverse opinions and groups of people, as this could lead to better designs and solutions: *"I would like to see a culture that is more open to more diverse opinions and diverse groups of people. Because when you have more diverse people on your team, [and] then you can design better for diverse people."* Lastly, many participants believed that managers and higher-ups have the power to change the

[1] Tradie is an Australian conversational form for tradesman, a skilled manual worker, generally in the construction industry. The term does not carry a negative connotation; it is, however, a vastly male-dominated sector.

Table 2. Categories and story examples

Category	Story Examples
Protagonist Empowerment	**protagonist :** "I felt undermined by your joke. I hope you don't view me like that." **Joker:** "Thank you for letting me know privately. I'm sorry that I offended you. I will avoid these jokes in the future." (See Figure 3)
Community and Bystander Support	**Protagonist:** Did you hear that?!? It's not the first time! He should stop! **Bystander:** "Stop! It's inappropriate to talk like that at work!"
Community and Bystander Support	**Boss:** "Hi Averil, I heard from … regarding your situation and wanted to let you know that I am here to support you. I feel that this is unfair and if you would like, I wanted to bring this up with others to see if we can help your situation." **Bystander:** "We wanted to help you, Averil. Please let us know because we don't think this is right." **protagonist (thinking):** "I don't feel so alone in this now. I feel supported."
Activism	**Bystander 1:** "I'm sorry about what just happened. We should talk to our colleagues and reach out to the school." **Protagonist:** "Thanks, I think that would help others who will be in my situation in the future." **Bystander 2:** "I would like to help, too!"

culture in the workplace*: "I think managers and higher-ups do have more power to change the culture."* They expressed their desire to see a culture led by people who celebrate diversity.

4.3 AR Fictions

As a final step in the workshop discussion, we asked the participants to imagine augmented reality applications for contributing to diversity initiatives in STEM. The participants were tasked with creating their story based on the prompt, "Imagine what happens next in the story." See Figure 1 for a picture of participants crafting their scenarios. The resulting stories were categorized into themes: protagonist empowerment, bystander support, and activism. A subset of the narratives portrayed a strengthened protagonist confidently addressing offensive or discriminatory behaviour. Additionally, many stories underscored the significance of community and bystander support in instances of discrimination. Certain narratives depicted the protagonist and bystanders proactively taking measures to ensure ongoing support for others facing similar discrimination within the community. Specific examples of these stories are detailed in Table 2, and one illustrative scenario is highlighted in Figure 3.

We distilled three directions from the participants' design fiction: brainstorming solutions, situated storytelling, and bystander simulations. The imagined augmented reality fictions are outlined as follows:

4.3.1 Platforms for brainstorming solutions. One of the participants suggested a platform that functions as a discussion forum to solve tensions within a community without pointing fingers. They envisioned a platform where others could contribute to the design of something helpful instead of feeling like a part of the problem.

Fig. 3. Example of a story showcasing an empowered protagonist.

> ***Participant 9:*** *"It would be interesting if there was a way to use AR to involve people in contributing to the design of solutions, rather than making them feel like they are part of the problem. They could examine scenarios and suggest potential interventions."*

4.3.2 Platforms for situated storytelling and sharing experiences. Other participants proposed platforms where people could anonymously share their experiences and participate in defining community values and acceptable behaviour. One participant highlighted that situated AR could be used as an ad hoc "reporting tool," making it visible how pervasive moments of discrimination are.

> ***Participant 10:*** *"I'm curious if AR could anonymously bring people together to share stories. It could create a space for people to understand what's acceptable and what's not."*

> ***Participant 8:*** *"I like using AR, even on a phone, to situate things in a university setting, adding more realism. Hypothetical situations are good, but reacting in the moment is crucial. You could scan yourself into a scenario, becoming one of the characters. Then, users could generate scenarios anonymously, serving as an interesting tool for reporting incidents around the university."*

4.3.3 Platforms for practising how to respond: "bystander simulations". Based on our research findings, we propose that when creating AR experiences to advocate for women in STEM, users must be positioned not as passive observers but as active participants. By engaging in self-reflection and collective understanding, users can contribute meaningfully to the narratives.

> ***Participant 8:*** *"You could have people who need sensitivity training or conflict resolution face these scenarios in a more realistic environment. Trying to resolve these situations in a practical setting could be super interesting."*

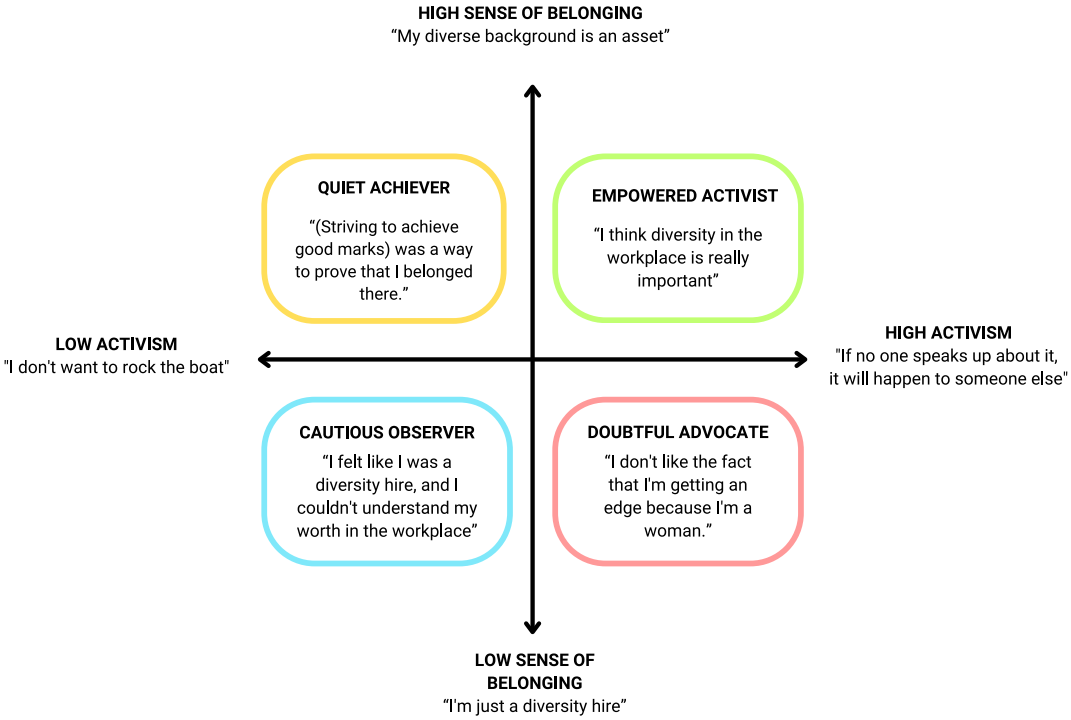

Fig. 4. Belonging/Activism Matrix

Participant 12: *"Imagine if there was a game where you get to pick different story alternatives. You consider various scenarios and see them play out. For example, if you come across a situation, should you step in or not? What happens based on your choice?"*

Participant 4*: "Going through a scenario with an AR headset could be quite interesting. You're in different situations, and different scenarios play out. I also think, like, going through your journey, quizzing the person could be cool."*

Participant 3: *"You could create a more immersive scenario with AR. Picture yourself there with Averil, her boss, and the bystander. Being in that context, you can see how close the bystander is and figure out the appropriate reaction. Maybe even see facial expressions for more emotional context."*

4.4 Archetypes of Attitudes in the Belonging/Activism Matrix

Based on the thematic analysis, observations, comic-based prototypes and interview quotes, we developed a 2x2 matrix with four archetypes of behaviours or attitudes, see Figure 4.

These archetypes emerged from refining and reorganizing quotes and themes in subsequent iterations of the analysis process. Our preliminary themes included belonging, influence, in/security, and support. The AR Fictions created by the participants during these discussions were categorized into themes of protagonist empowerment, bystander support, and activism. As belonging and security seemed to go hand in hand, we combined these two into a "sense of belonging"

and changed "influence" to "activism." We then added these two as the opposite ends of a matrix: a high/low sense of belonging and high/low activism. The archetypes are as follows:

- **Doubtful Advocate** (High Activism, Low sense of belonging): This archetype encapsulates high activism yet low belonging, characterized by frustration with the status quo and disempowerment to effect change.
- **Cautious Observer** (Low Activism, Low sense of belonging): This archetype represents states where one feels out of place and lacks the drive to effect change, choosing to observe rather than participate.
- **Quiet Achiever** (High sense of belonging, Low activism): This archetype signifies states where one works hard to prove their worth or fit in, feeling a strong sense of belonging but lacking the drive to challenge the status quo.
- **Empowered Activist** (High activism, High sense of belonging): This archetype embodies states where one is driven to change the status quo and feels a strong sense of belonging, motivated to effect change.

These archetypes do not describe individuals but rather a state in time. Some participants described a journey from one state to another. All of these dimensions co-existed in each participant to some degree, and they are not mutually exclusive but represent different competing positions that participants sometimes struggled to reconcile. In other words, they change over time based on different variants. Many participants reflected on past experiences of being a "cautious observer" and, over time, developing a sense of belonging through role models or finding a group where they felt accepted and valued, thus becoming either "quiet achievers" or "empowered activists."

See Table 3 for example quotes for the identified emotions and archetypes.

5 DISCUSSION

Building on the archetypes of attitudes in the Belonging/Activism Matrix, this study explores the intersection of Augmented Reality (AR), storytelling, and Feminist HCI to address gender diversity in STEM. The archetypes, derived from conversations in the AR co-design workshop and subsequent semi-structured interviews, represent the main contribution of this paper. They provide a nuanced understanding of the varying attitudes and behaviours within the STEM community, offering valuable insights for future diversity initiatives. With its ability to overlay digital narratives onto the physical world, AR is a powerful tool for making these archetypes and their stories visible and tangible [5]. As Azuma [6] notes, storytelling is fundamentally important in exploring alternative futures and understanding the context of novel designs and technologies [3, 12, 25]. Simultaneously, this research adopts a Feminist HCI lens to address gender disparities in STEM [15, 27]. This approach acknowledges the symbolic coding of technology as masculine and its impact on women's performance and opportunities in STEM [15]. It also recognizes the need for more inclusive designs and practices that accommodate varying and fluid genders [7, 10, 51, 58].

RQ1: *How do students in STEM Higher Education perceive and experience gender diversity within their fields?* The workshops and interviews revealed diverse experiences and perceptions of gender diversity in STEM, echoing the broader discourse on the masculine culture of technology [22, 51, 59]. Some participants expressed tension, frustration, and self-doubt, which can be attributed to phenomena like stereotype threat [47] and imposter syndrome [19]. They felt uncomfortable receiving an advantage solely because of their gender, reflecting the need for a community culture that values different backgrounds [41].

RQ2: *How do students in STEM Higher Education envision using augmented reality as a medium for supporting diversity initiatives?* Participants envisioned AR applications contributing to diversity initiatives in STEM. They suggested platforms for brainstorming solutions, situated storytelling, and bystander simulations. These ideas align with the existing work on immersive technologies as 'empathy machines' in diversity, equity, and inclusion [28, 31, 32].

Table 3. Quotes from the interviews and workshops

Emotion	Archetype	Quotes
Frustrated	Cautious Observer	"And this one guy, I remember right before an exam, he was saying that he was having difficulty getting an internship. Moreover, he said all the women and people of colour were taking all spots."
	Doubtful Advocate	"These comments certain people were making, you know, 'that's good for a woman,' or whatever. Those comments were not necessary; they were harmful."
	Doubtful Advocate	"He would make those sorts of comments like, 'That's good for female' and things like that, but I was getting better grades than him. So, you know, it angered me."
	Doubtful Advocate	"I have been to interviews when they've said, 'Oh, your resume is good, but we will only hire guys. It's just company culture. We want to be comfortable. We can't hire women.'"
	Doubtful Advocate	"I don't like that I am getting an edge because I'm a woman."
Sad	Cautious Observer	"That pushed down my self-esteem because later I had this mindset: 'I'm just a diversity hire.'"
	Cautious Observer	"I feel like what my past experiences, being an intern in corporations, sometimes I feel inferior to others, alone, lonely."
	Quiet Achiever	"I just worked hard and ensured my GPA was always way higher. And that would usually shut them off. But that was the only thing that did."
	Quiet Achiever	"They'll give you an official mentor that you would talk to about career progression. And there's just kind of this subtle thing that they tell you: "Here are some things that you need to do to mitigate some of those problems that will come up. This is how you need to act in a meeting, and it will be different to how the other people might have to act in the meeting. And it sucks, but you must do it.'"
	Quiet Achiever	"There's also this emotional labor that goes into managing other people that don't want you in STEM. Yeah, they maybe feel uncomfortable with your presence."
Optimistic	Empowered Activist	"And I'm not just a diversity hire, I have something to bring. I think diversity of workplace is important."
	Empowered Activist	"You know, they see that it's not just like, coding away in a dark room or something, you know, you can enjoy making these things."

5.1 Design Implications

The four archetypes of behaviours or attitudes developed based on thematic analysis, observations, and interview quotes. These dimensions co-existed in each participant and represented different competing positions. Recognizing this fluidity can help researchers understand user journeys and the factors influencing transitions between these states.

In the context of interventions, creative problem-solving plays a pivotal role, extending beyond merely understanding someone's experience. Instead, empathy becomes most effective when it facilitates reaching out to others [60]. Recognizing that others are empathetic toward us can lead to a sense of belonging, reduces isolation, and alleviates

shame [60]. An example of how to use the archetypes as a framework ties into the participant's co-created AR Design Fiction:

- **Platforms for brainstorming solutions:** A participant who identifies as a Doubtful Advocate might feel frustrated with the status quo of diversity in STEM. They could use the AR platform to brainstorm solutions, voice their concerns, and contribute to designing interventions without feeling like they are part of the problem. Over time, this could help them transition towards becoming an Empowered Activist as they see their ideas being implemented and making a difference.
- **Platforms for situated storytelling and sharing experiences**: A Cautious Observer might feel out of place and choose to observe rather than participate. They could use the platform for situated storytelling and sharing experiences to anonymously share their experiences and learn about community values and acceptable behaviour. This could help them transition towards becoming a Quiet Achiever as they better understand the community and feel a sense of belonging.
- **Platforms for practising how to respond** ("bystander simulations"): A Quiet Achiever works hard to prove their worth or fit in. They might use the platform for practising how to respond, or "bystander simulations", to prepare themselves for potential situations of discrimination or bias without challenging the status quo directly. This could help them transition towards becoming an Empowered Activist as they gain confidence in their ability to respond to these situations. An Empowered Activist is driven to change the status quo and feels a strong sense of belonging. They might use the platform to brainstorm solutions and actively contribute to the design of interventions. They could also use the platform for practising how to respond, or "bystander simulations", to prepare themselves and others for potential situations of discrimination or bias.

Based on our research findings, we propose that when creating AR experiences to advocate for women in STEM, users must be positioned not as passive observers but as active participants, reflecting feminist HCI qualities [7]. By engaging in self-reflection and collective understanding, users can contribute meaningfully to the narratives.

The research also explores the potential of using augmented reality to support diversity initiatives. This could involve developing platforms for brainstorming solutions, sharing experiences, and practising responses to discriminatory behaviour. The participants of this study identified a need for platforms where people can anonymously share their experiences and participate in defining community values and acceptable behaviour. This could involve creating safe online and offline spaces where students can share their experiences without fear of retribution. The research highlights the potential of using AR for sensitivity training or conflict resolution. Institutions could consider incorporating such technologies into their training programs to provide a more realistic and immersive learning experience.

Finally, here are some ideas on how these archetypes can be used to inform the design of technological interventions:

(1) **Understanding User Journeys:** The archetypes represent different states or attitudes individuals may experience at different times. Recognizing this fluidity can help researchers understand the user journeys and the factors that influence transitions between these states. For instance, one participant reflected on their journey from being a "Cautious Observer" to an "Empowered Activist": *"And this one guy, he was saying that he was having difficulty getting an internship. He said all the women and people of colour were taking all spots."* to, later on, reflect that *"(Overtime) I realised that I'm not just a diversity hire, I have something to bring."*

(2) **Tailoring Interventions:** By understanding these archetypes, interventions can be tailored to meet each group's unique needs and challenges. For example, initiatives for the "Doubtful Advocate" might address feelings of imposter syndrome, while those for the "Empowered Activist" might leverage their optimism and activism.

(3) **Fostering Empathy**: These archetypes can foster empathy among peers and educators in STEM. By sharing these stories, others can better understand individuals' various experiences and obstacles in these fields. Furthermore, these tools could aim for two-directional empathy, providing opportunities for conversation and not just automated viewing of others' perspectives.
(4) **Informing AR Design:** The insights from these archetypes can inform the design of AR applications to encourage self-reflection and collective understanding. For instance, AR experiences could be designed to allow users to 'walk in the shoes' of each archetype, promoting empathy and understanding. Innovators like Milk [40] view immersive technology as a means of automated empathy, offering a simple solution to complicated, social, emotional, and intricate issues, such as increasing inclusivity and diversity in STEM. Rouse comments that this perspective caters to a fantasy that aligns with a privileged position. It seeks "quick, easy, and relatively painless ways to mitigate issues that fall short of actual change" [52]. Our research addresses this by directly involving participants and emphasizing their role as active contributors to the design process.
(5) **Evaluating Impact**: These archetypes provide a framework for evaluating the impact of diversity initiatives. Researchers can measure shifts in attitudes and sense of belonging by understanding where individuals sit within these archetypes before and after interventions.
(6) **Forming Alliances**: Understanding these archetypes could also help build alliances. Allies who understand the different experiences and challenges faced by individuals in these archetypes are less likely to feel 'walking on eggshells' and more likely to be part of the solution. For example, comprehending the perspective of a "Doubtful Advocate" can help allies understand the dilemma of wanting to advocate for change but feeling like an imposter. Similarly, understanding the "Quiet Achiever" can help allies appreciate the emotional labour that goes into managing others who may not want them in STEM. This understanding can lead to more constructive interactions and stronger alliances.

The experiences and perceptions of gender diversity in STEM, as revealed by our participants, align with the broader discourse on the masculine culture of technology [22, 59]. AR as a medium for supporting diversity initiatives also builds upon the existing work on immersive technologies as empathy machines in diversity, equity, and inclusion (e.g. [28, 31, 32]). The design implications derived from our study offer practical ways to address the challenges identified in the background, such as the underrepresentation of women in STEM and the identified need for more inclusive cultures that value diversity and different backgrounds [42].

5.2 Limitations and Future Work

Our study explores using augmented reality co-design to advocate for women in STEM higher education, acknowledging the multifaceted nature of diversity. While our method shows promise, it does not claim generalizability. Our recruitment strategy, which leveraged the authors' networks and university email lists, may have introduced bias. However, this approach built trust with participants and aligned with our commitment to community-centric research. This recognition underscores the need for broader research and exploration. Based on a limited number of participants, the findings provide a snapshot of experiences at a specific time, place, and institution and do not represent all STEM contexts. Despite these limitations, the study offers valuable insights into women's experiences in STEM and the potential of AR in advocacy. Future research could address these limitations by employing a mixed-methods approach, increasing the sample size and diversity, incorporating longitudinal data, and developing and testing the envisioned AR applications.

6 CONCLUSION

In conclusion, by focusing on the experiences and perceptions of students in STEM Higher Education, this research has explored gender diversity in STEM fields and produced a valuable matrix that can assist in developing future and higher-quality studies. Our study identified four archetypes of attitudes towards discrimination: Doubtful Advocate, Cautious Observer, Quiet Achiever, and Empowered Activist. These archetypes offer a conceptualisation of how individuals perceive, react to, and potentially intervene in instances of discrimination. The employed co-design workshop, the Identity Workshop, utilized augmented reality design fiction (AR) for prototyping and storytelling, offering a novel approach to addressing diversity issues. The participants envisioned AR applications for brainstorming solutions, situated storytelling, and bystander simulations, which can lead to more self-reflection and better collective understanding.

In conclusion, our research underscores the potential of immersive technologies, such as AR, in supporting gender diversity initiatives in STEM. It invites further investigation into refining the Identity Workshop, developing the envisioned AR applications, and testing their impact on empathy and engagement. Future research could also explore the workshop method with a broader participant set, considering intersecting aspects of diversity such as race and disability. This research is a stepping stone for striving for a more diverse and inclusive STEM education environment. It highlights the necessity for creative strategies and ongoing advocacy to support women in higher education STEM fields and create a culture that values diversity and inclusivity.

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A APPENDICES

A.1 Semi-structured interview plan

Duration: 45 min **Aims:** To understand how people frame the problem, how they act on it, and what phenomena they describe that could be utilized in diversity training.

(1) To get started, can you tell me briefly about yourself?
   (a) Probe: What is your current occupation?
   (b) Probe: Do you have a family? *(This is to assess the support the person might require not just in the workplace or in the family. One concerns in STEM is the lack of support for people with caring responsibilities)*
(2) Could you describe what made you interested in contributing to diversity in STEM?
   (a) Probe: What changes do you wish to see within STEM culture?
   (b) Probe: What do you see as the issue?
(3) Are you part of a community or organization that works to improve STEM diversity? (If yes, ask follow-up questions)
   (a) How did you get involved with this organization? What inspired you to join?
   (b) If it is okay to share – What is your opinion on the difference it is making?
   (c) What are your main aims or goals?
(4) Could you describe one of your most interesting experiences in STEM?
   (a) Probe: Is there a project/event/ you are proud of?
(5) Could you describe one of your most challenging experiences and explain how you dealt with it?
   (a) Probe: Do you experience pushback? What kind?
(6) Would you have questions about my research?
(7) Anything else you would like to expand on?

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