From Participation to Production: A Call to Action for Reconceptualizing Socio-Technical Systems through a Gender-Inclusive Design Framework*

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Abstract

While Socio-Technical Systems theory emphasizes democratic participation, its foundational principles often operate under a "gender-blind" paradigm, assuming neutral users and designers – a perspective that frequently defaults to an implicit "I-methodology" dominated by masculine cognitive styles and risk attitudes – thus failing to address the systemic biases inscribed in ICT production. This position paper argues that moving beyond functional neutrality requires a shift from inclusive usage to inclusive production and lays the groundwork for a gender-aware STS field across two integrated levels. First, at a theoretical level, it revisits Cherns' seminal principles to establish a new systemic baseline for organizational design, embedding women leadership, active bias mitigation, pluralistic interactions, and sustained equity. Second, at an operational level, it maps existing gender-aware literature and methodologies to the sociotechnical hexagon, structuring them into an actionable framework open to future extensions. Ultimately, this reconceptualization serves not as a closed taxonomy, but as a proof of concept and a call to action for the STS community to collectively build a living repository for inherently inclusive gender-aware design.

Keywords

Socio-Technical Systems, gender-aware design, gender-neutrality myth, operational framework

1. Introduction

Although the Socio-Technical Systems (STS) tradition has historically emphasized the inseparable interaction between human, organizational, and technological components [8,9,12,26], the gender dimension remains largely unexplored or marginally addressed within design methodological frameworks and insufficiently theorized [2,34]. The persistent underrepresentation of women in ICT production and the illusion of a "neutrality of technology" often result in interactive systems that reflect and amplify existing asymmetries and stereotypes, lacking a truly inclusive nature [3,13,39]. We believe that addressing the gendered structuring of technology is not simply a matter of social equity, but a fundamental requirement for the methodological robustness and resilience of sociotechnical design itself. To do so, we propose a theoretical position that, while building on the foundations of the STS debate, questions the discipline's traditional boundaries.

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This call to redraw these boundaries deeply resonates with the call for 'bravery' launched by Davis et al. [12]. In their 'manifesto' for the future of socio-technical approaches, the authors urge the scientific community to transcend traditional domains of corporate IT to embrace grand global challenges, moving towards a *predictive dimension of systemic failures*. However, if Davis et al.'s proposal moves primarily along a sort of 'horizontal' axis, advocating for broadening the range of application domains and in this way providing answers to major societal challenges (such as security, crime, health and social care, or the design and functioning of future cities), we move along an orthogonal 'vertical' axis, positing that – regardless of the application domain (whether new or old) – there is an intrinsic, pervasive, and thus far non-systemically addressed dimension: the gendered structuring of technology and design processes. It's not enough to just look elsewhere, we need to look deeper.

Gender is an inherently complex, dynamic, and non-binary social construct that intersects with broader socio-cultural vectors (such as race, class, and context) [3,11,34]. Addressing this full spectrum requires collective, multi-perspective engagement across the broader scientific community. Accordingly, this position paper does not claim to address the gender dimension in its entirety. Rather, it aims to serve as a proof of concept focused specifically on **women-centered** perspectives and structural inclusion, an emphasis chosen in alignment with the urgent mandates of the UN Sustainable Development Goals (SDGs 5 and 10) [36]. By narrowing our analytical scope to this specific, well-documented dimension of systemic exclusion, we aim to demonstrate the viability of a gender-aware socio-technical reframing, paving the way for future extensions by the STS community.

1.1. From Gender-Blindness to Systemic Failures: Concrete Instances

Gender-blindness in design does not merely produce isolated bugs; it systematically generates structural failures across multiple operational dimensions. At the **technical and interactional level**, assuming a monolithic, "default" user not only produces algorithmic bugs and severe performance defects, but also leads to algorithms and interfaces that ignore gender-differentiated cognitive styles, learning patterns, and problem-solving strategies, thereby possibly erecting invisible cognitive barriers for women [7]. Simultaneously, at the **socio-organizational level**, the absence of gender-oriented auditing mechanisms allows discriminatory practices and unbalanced structural patterns to remain embedded within institutional workflows [10]. When technology design overlooks these dual dimensions, systemic failures become predictable outcomes rather than anomalous disruptions. To illustrate how these dual mechanisms operate in practice, we briefly examine two pervasive domains: computer vision and voice recognition.

In image recognition technologies, for instance, technical-level algorithmic disparities are particularly evident: commercial image recognition and facial analysis algorithms exhibit severe demographic disparities, suffering from misidentification and false-negative rates that may be of orders of magnitude higher when processing images of women [15,28]. Beyond recognition errors, technical vulnerability manifests as a socio-political problem of professional representation: commercial classifiers exhibit strong semantic bias, systematically failing to tag women in professional or executive roles and disproportionately reducing them to appearance-based metadata [28]. This professional invisibility is further amplified in generative AI models, where women are virtually absent in generated depictions of high-status occupations [14],

demonstrating how design-level gender blindness actively codifies socio-economic marginalization, thus perpetuating and possibly amplifying it.

This pattern of systemic failure is equally evident in voice recognition technologies: studies demonstrated that Google's recognition software was 70% more likely to accurately process men speech than women speech [33]. In everyday, non-critical usage, this disparity means that women effectively pay the same price for a degraded user experience and suboptimal service quality. However, when applied to safety-critical contexts (such as surgical voice-control systems or automotive voice commands) this design blind spot predictably turns into high-risk, dangerous systemic failures.

This phenomenon is also documented by [10], who reports the illustrative stance of a top executive at a major car navigation systems manufacturer: addressing the persistent glitches in voice recognition for women drivers, the executive asserted that while the software had already been fixed "*for the many issues with women's voices*" remaining difficulties could be easily overcome if women users simply underwent "lengthy training", implicitly shifting the burden of system inefficiency onto women themselves (who stubbornly refuse to sound like men!).

This resonates with Sally Wyatt's critique in her analysis of feminism, technology, and information society, emphasizing that women have historically been positioned either as passive recipients of technology or as problematic users who need to be "trained" to adapt to man-centric artifacts [41]. The "fix the women, not the system" mindset exemplifies also what Judy Wajcman forcefully critiques [39]: rather than demanding that users adapt, it is technoscience itself that must be reshaped to "accommodate women." A goal ideally implicit in the variety of existing human-centered design methodologies, but again failed to be achieved due to gender-blindness and hypothetical neutrality. As Wajcman argues, under current technological paradigms, women are too often expected to "*exchange major aspects of their gender identity for a masculine version, whilst there is no similar 'degendering' process prescribed for men*" [39].

1.2. Revisiting Socio-Technical Principles through a Gender Lens

To move beyond the systemic failures of gender-blind design, socio-technical systems engineering must hence undergo a fundamental conceptual shift. Rather than attempting to adapt "women-related fixes" onto man-centric default architectures, the foundational principles underlying system design, governance, and evaluation must be explicitly re-examined through a gender-sensitive lens. Originally conceptualized to ensure that technical, human and organizational factors are harmonized in the design process, classical socio-technical design principles offer a robust structural foundation and should hence lead to a somehow implicit inclusive nature [25,26]. However, being conceived under the assumption of a neutral, universal user, they inherently carry the risk of perpetuating structural inequities (and hence implicit exclusion) if these are left unexamined. Addressing this blind spot requires embedding explicit gender-responsive criteria directly into the foundational frameworks, ensuring that socio-technical systems systematically evolve from instruments of hidden possible exclusion into platforms for genuine equity.

To advance this re-engineering agenda, this **position paper** further develops core insights from a previous study of ours [32], where we drew a parallel between multidisciplinarity and the need for a multigender approach underscored by Clegg's principle 17 ("Design involves multidisciplinary education") [9] and reinterpreted his considerations through a gender lens:

"*A further potential benefit exists: a multi-gender approach to design is more likely to foster creative and innovative solutions. Whilst this may seem obvious, an approach based on gender equality explicitly assumes that design needs to draw upon the expertise of all genders. This requires considerable resources and support.*" [32].

It is however clear that the re-interpretation of a single principle – though a promising starting point – cannot be sufficient for dismantling gender-blindness and that a broader, systemic intervention across the entire discipline is required, leading us to formulate our main Research Question:

- **RQ0:** *How can foundational Socio-Technical Systems (STS) frameworks be reframed to move beyond gender-blindness and gender-neutrality, paving the way for inherently inclusive sociotechnical design?*

To address this core question, we decompose it into two complementary research dimensions, tackling the theoretical foundations and their operational translation into design practice:

- **RQ1 (Theoretical/Systemic Baseline):** *In what ways can sociotechnical theory move beyond functional neutrality to systematically incorporate inclusive governance, active bias mitigation, pluralistic interactions, and sustained equity over time into organizational design?*
- **RQ2 (Operational/Methodological Framework):** *How can existing gender-aware methodologies and critical tools scattered across literature be systematically structured into an actionable framework for practitioners?*

It is important to emphasize that the reconfiguration proposed in this paper does not claim to be an exhaustive or definitive framework. It is rather conceived as an initial, open-ended invitation to the socio-technical research community: dismantling embedded gender-blindness should be an inherently collective and iterative effort. The goal of this paper is therefore to establish a shared foundation to spark ongoing dialogue, encourage multi-perspective contributions, and collectively shape more gender-inclusive design practices.

To address this objective and provide first answers to the research questions, this position paper lays the groundwork for a gender-aware STS field by retracing selected milestones of its evolutionary trajectory across the following sections. After addressing the myth of gender-neutrality in Section 2, Section 3 tackles RQ1 by revisiting Cherns' foundational principles through a gender-aware lens to establish a new theoretical baseline for organizational design. Section 4 then addresses RQ2 by operationalizing Davis et al.'s sociotechnical hexagon through a gender-aware lens, mapping existing literature and critical methods into an actionable framework for practitioners. Finally, in Section 5, conclusions are drawn and future directions for the STS community are outlined.

2. Gender-Blindness and Gender-Neutrality: Two Paths to the Same Invisibility

The socio-technical approach to the design, since its origins in the work of the Tavistock Institute has aimed at the goal of jointly optimizing social and technical systems [26]. However, a contemporary re-reading of seminal contributions of the field reveals a significant gap: the assumption of a (hypothetically) "neutral" subject that, in effect, ignores power dynamics and cognitive differences related to gender.

At a foundational level, Mumford's (re)definition of the Socio-Technical approach as "*one which recognises the interaction of technology and people and produces work systems which are both technically efficient and have social characteristics which lead to high job satisfaction*" [25] addresses the necessity of recognizing the needs of people and might be hence regarded as implicitly anticipating human-centric diversity. However, such foundational goodwill remains insufficient since inequalities cannot be dismantled if not *explicitly* addressed [32].

This theoretical blind spot directly impacts concrete design guidelines. Let us consider, for instance, Cherns' principle of "Minimal Critical Specification", which encourages avoiding overspecifying processes and tasks to grant users operational autonomy [8]. While sound in theory, this principle implicitly presupposes a user with high technological self-efficacy and a specific willingness to experiment. On the other hand, studies demonstrate that many "poorly specified" software environments or trial-and-error design patterns create cognitive barriers for women, not due to a lack of ability, but due to a different attitude to risk and problem-solving that designers often ignore [7]. This dynamic is additionally coupled with systemic contexts and second-level digital gender divides, where socio-cultural factors and unequal technological exposure further shape self-efficacy, tech confidence, usage patterns, and risk perception [1]. Far from reflecting inherent biological traits, these empirically observed tendencies underscore how gender-aware design must accommodate diverse operational preferences without re-inscribing traditional stereotypes.

This operational neglect may also be further compounded by those who steer the design trajectory and make key technical decisions. To address system complexity, Clegg's Principle 17 (Multidisciplinarity) suggests that design should involve diverse professional skills [9]. Yet, as Science and Technology Studies demonstrate, multidisciplinary diversity does not automatically guarantee gender inclusion. In the absence of explicit gender diversity within technical teams, the so-called "I-methodology" is inevitably triggered: designers (historically and predominantly men) unconsciously project their own cognitive preferences, risk attitudes, and daily workflows onto the technical artifact [39].

This brings us to the core limits of traditional STS participation. Relying on Mumford and Beekman, STS theory warns that "*If a technical system is created at the expense of a social system, the results obtained will be sub-optimal*" [27]. However, can the simple participation to the design process of women on the final utilizers' side be considered enough to this aim?. As Wajcman argues, participation risks becoming a form of symbolic inclusion if it fails to address power structures: if decision-making processes remains unchallenged, technological expectations continue to be mediated by unwritten gender norms and guided by a collective vision dominated by pre-existing, intrinsically man-centric organizational structures [39].

In summary, STS "neutrality" morphs into a form of gender blindness: treating gender as an irrelevant variable in sociotechnical design leads to the creation of systems that perpetuate ecosystems in which women may feel like (even unexpected) "guests".

This pattern is historically evident also in related fields: the taken-for-granted association between men and machines is clearly exemplified by the fact that the initial denomination for Human-Computer Interaction was Man-Machine Interfaces, a terminology that dominated scientific literature through the 1970s before being progressively abandoned in the early 1990s (with the International Journal of Man-Machine Studies officially changing its title only in 1994 to International Journal of Human-Computer Studies (IJHCS). This initial naming exposes a historical paradox: it is quite peculiar that the discipline whose mission was to make technology friendly for all users was simply ignoring half of the population, assuming a gender divide already at utilization level, left alone the production level.

Actually, moving from an exclusive to a neutral approach proves to be only a partial solution. An interesting 2015 study [6] identified the top five words used to reference people in the CHI 2014 proceedings (the top HCI international conference), discovering that they were all gender-neutral: user, participant, person, designer and researcher. On the other hand, when presented to a sample of about 430 subjects, these terms were overwhelmingly perceived as referring to a man by male participants (80% or above for all terms but 'designer' that was anyhow about 70%). Interestingly enough, the remaining part was split among 'female', 'non-human' and 'unknown'. Women were slightly less gender-biased, with 'user' and 'designer' around 60%, 'researcher' around 70% and only 'person' and 'participant' almost evenly split between 'male' and 'female'.

These findings suggest that the path of neutrality does not effectively resolve gender bias nor bridge the gender gap. Rather than pursuing gender-neutrality, we should hence explicitly acknowledge and emphasize gender: as observed by Wajcman, the gendering of technologies must not only be shaped or reconfigured at the multiple points of consumption but must also be understood as shaped in design, with technology as both a source and consequence of gender relations [39], within a social constructivist framework adopted also by feminist Science and Technology Studies scholars (e.g., [13,24]). On the one side, individuals demonstrate their gender identity in part through their daily use of objects and, on the other side, technological innovations may change the nature and meaning of tasks and consequently social contexts. Can women still be excluded from the processes of technical design that shape the world we live in? [39]. In the same direction, Caroline Criado Perez argues that "*the gender data gap is both a cause and a consequence of the type of unthinking that conceives of humanity as almost exclusively male*" and that "*failing to include the perspective of women is a huge driver of an intended male bias that attempts (often in good faith) to pass itself as gender-neutral*": to design a world meant for everyone "*we need women in the room*" [10], engaging with the epistemological foundations of feminist technology studies.

Feminist Standpoint Theory (pioneered by Sandra Harding [18-20]) posits that knowledge and technology are never socially neutral but rather constructed from specific social positions. Technical design has historically operated under the illusion of a universal, objective viewpoint (Donna Haraway's "god trick" [17]), an illusory vision from nowhere that in reality reflects a privileged, 'default male' perspective. The concept of **situated knowledges** reminds us that all knowledge (and, consequently, all technological design) is partial, embodied, and rooted in specific lived experiences [17,18]. Merely adding women to an unchanged, male-

dominated structure does not automatically transform the system if their unique, situated experiences are not allowed to inform the underlying design logic. This critique is further operationalized in contemporary socio-technical contexts by D'Ignazio and Klein's **Data Feminism** framework, positing that addressing technological inequities requires explicitly examining and challenging how power operates in data and design ecosystems [11]. Co-creation cannot be reduced to symbolic tokenism or superficial user-testing; it demands a radical shift that elevates marginalized perspectives to actively shape system architectures, decision-making processes, and governance.

Although debated in the literature, **standpoint theory** offers clear epistemological advantages for design: those who – due to their social position – are continually forced to negotiate within the world of the privileged end up with a deeper understanding of both the dominant worldview and the reality of the marginalized community. The **marginalized standpoint** raises the standards of empirical adequacy since it pushes us to considerate hypothesis, lines of evidence, and models often overlooked by the dominant view. Gender is one dimension of social differentiation that may make such a difference epistemically [42].

Without this epistemological grounding, user participation risks becoming just an illusion of inclusion, continuing to mask systems that treat androcentric norms as the universal baseline (Criado Perez's "default male" vision [10]) and – as also previously remarked – continuing to position women merely as often unexpected guests rather than true co-creators.

3. Revisiting Cherns' principles under a gender-aware lens

To anchor our vision in the foundational roots of Socio-Technical Systems, we chose to adopt Cherns' seminal principles [8] as a first *paradigmatic testbed* for a gender-aware revisiting. Rather than attempting an exhaustive re-examination of STS theories, we intentionally focus on a concise core of essential principles, returning to the field's point of departure. This selective revisiting serves as an *illustrative framework* to demonstrate how embedding gender dynamics at the very foundation may reconfigure the structural assumptions of sociotechnical design.

To address the various issues emerged from the discussion so far, this reconfiguration effort spans across four interconnected dimensions:

- **participatory governance**, ensuring women leadership, transparency, and active involvement in technical decision-making (addressed by *Principles 1 and* 6);
- **bias mitigation and safety**, systematically identifying cognitive and algorithmic biases while establishing psychological safety within digital environments (addressed by *Principles 2,3, and 8*);
- **plurality and life-work harmony**, accommodating diverse interaction pathways and respecting the boundaries of unpaid care work (addressed by *Principles 4 and 5*);
- **structural equity and continuous audit**, guaranteeing fair career and evaluation trajectories through ongoing, longitudinal inclusion audits (addressed by *Principles 7 and 9*).

By embedding gender-responsive criteria directly into Cherns' framework, sociotechnical systems can systematically evolve from instruments of implicit exclusion into platforms for genuine structural equity. Table 1 summarizes the gender-sensitive reinterpretation of Chern's

principles, while in the following we more extensively comment on each principle, building on the gender-aware lens previously discussed.

Table 1
Comparative overview of traditional sociotechnical design principles versus their gender-sensitive reinterpretation.

Cherns' principle	Traditional focus	Gender-aware lens
1. Compatibility	A process consistent with objectives.	Design teams and co-design processes that are inclusive and free of power asymmetries.
2. Minimal Critical Specification	Do not specify more than necessary.	Avoid allowing the "unspecified" to become the default. Co-define "minimal specification" with women. Ensure multiple cognitive pathways.
3. Socio-Technical Criterion	Variances controlled at the source	Prevent and eliminate bias, harassment, and privacy and vulnerability leaks at the source rather than delegating remedial or protective work to the user.
4. Multifunctionality	Flexibility and redundancy of functions	Plurality of interaction paths (equifinality) to embrace different profiles and needs.
5. Boundary Location	Boundaries based on technology/time/space	Respect and protection of the boundaries between work, private life, and care burdens.
6. Information Flow	Data directed to those who need to act	Transparency on hidden disparities through gender-disaggregated data, protection from targeted gendered digital harms.
7. Support Congruence	Aligned reward/evaluation systems	Neutralization of gender penalties in organizational evaluation and support systems.
8. Human Values	Quality of work, learning, autonomy	Inclusion of gender equity, psychological safety, and counteracting algorithmic bias.
9. Incompletion	Design is a continuous iteration	Gender inclusion as a process of continuous sociotechnical audit, not a static check.

Principle 1 – Compatibility. Cherns contends that the design process must be compatible with its objectives observing that a participatory system cannot be created autocratically: a constructively participative organization is needed where people are given the opportunity to participate in the design of the jobs they are to perform.

Gender-aware lens. A gendered reading of this principle highlights that the design process must explicitly address gender in order to reflect the diversity and inclusivity it aims to promote. Inclusive systems cannot be designed if the design team, co-design phases, and project governance suffer from occupational segregation or the "invisibilization" of women/marginalized voices. This requires that women and underrepresented groups actively hold design and decision-making roles within design teams and project governance. *Participation must extend beyond passive consultation to empower women leadership, actively defusing structural power asymmetries throughout the design process.*

Principle 2 – Minimal Critical Specification. This principle states that it must be specified only what is strictly essential, leaving room for user autonomy and adaptation ("don't design other people's lives").

Gender-aware lens. When something is left "unspecified," the empty space tends to be filled by implicit biases and dominant stereotypes (the "default male"). From a gender-aware perspective, *the "minimal specification" must therefore explicitly define the need for multiple cognitive pathways and styles* (e.g., learning styles, risk-taking propensity, gender dependent exploration modes) to prevent the absence of rules from resulting in the involuntary imposition of a single (usually androcentric) problem-solving model. The "minimal specification" should hence be co-defined with women in design and decision-making roles.

Principle 3 – The Socio-Technical Criterion (or "Control of variances at the source"**).** Cherns recommends that variances (unplanned events or deviations which critically affect outcome) must be controlled and resolved as close to their point of origin as possible.

Gender-aware lens. When explicitly addressing gender dynamics, this principle demands that "gender variances" (such as micro-aggressions, online harassment, privacy leaks, algorithmic bias, or usage failures related to different ergonomics/needs) must not be passed on to the end user as "emotional or reparative care work." (e.g., burdening users with complex, reactive privacy management or self-protection measures). *The system must integrate feedback, privacy protection, and vulnerability and bias prevention and mitigation mechanisms in situ* (e.g., within default privacy-by-design settings, the interface, or original data flow) before the bias propagates into systemic discrimination.

Principle 4 – Multifunctionality - Organism vs Mechanism. According to this principle, the organization/system must be based on the redundancy of functions (elements with multiple capabilities) rather than the redundancy of parts (hyper-specialized and interchangeable people/components).

Gender-aware lens. Applying a gender-sensitive view implies that *the system must offer multiple equifinal paths to achieve the same goal, accommodating a variety of user experiences.* There is no such thing as an "average user": multifunctionality ensures that interaction modes, communication styles, and workflows cater to a wide range of sociocultural backgrounds and gender identities without penalizing those who don't follow the standard path.

Principle 5 – Boundary Location. Cherns stresses that departmental/organizational boundaries should not be based solely on technology, territory, or time, but should facilitate knowledge sharing and autonomy.

Gender-aware lens. Reinterpreting this principle through a gender lens requires to recognize and deconstruct the transparency of boundaries between work, private, and care spheres (domestic/reproductive labor). Modern sociotechnical systems (e.g., remote working, smart homes, organizational apps) often invade or ignore these boundaries, overburdening women. *Design must define and protect the boundaries of responsibility, mental load, and privacy, avoiding reproducing traditional gender roles in managing information and time flows.*

Principle 6 – Information Flow. This principle dictates that information should be provided primarily at the point where action is needed, rather than being centralized for vertical control.

Gender-aware lens. A gendered reading of this principle implies that *the information and the data collected by the system must integrate the gender dimension to make otherwise hidden disparities visible* (e.g., gender-disaggregated dashboards, transparent workload metrics). At the same time, the information flow must be designed with strong attention to security, consent management, and the prevention of gendered surveillance, data exploitation, or Technology-Facilitated Gender-Based Violence (TFGBV). Re-engineering information flows from a gender-aware perspective requires recognizing privacy protection and data safety not as passive compliance features, but as a foundational safeguard. Sociotechnical design must proactively shield women and marginalized groups from targeted digital harms, consent violations, and tech-facilitated abuse (e.g., location tracking, image-based abuse, or algorithmic harassment).

Principle 7 – Support Congruence (Congruence of Support Systems). Cherns outlines the necessity for all support systems (evaluation, compensation, training, recruitment) to reinforce and support the behavior required by the sociotechnical structure.

Gender-aware lens. Applying a gender-sensitive view implies that *incentive, evaluation, and career progression/use systems must be systematically audited to prevent gender penalties.* If the sociotechnical system promotes collaboration and participation, but evaluation rewards individualistic styles or 24/7 availability (predominantly compatible with those without caregiving responsibilities), a structural incongruence is created. Support must be holistic and sensitive to real-life differences: designing for support congruence means preventing unjustified career/performance penalties related to caregiving responsibilities, flexible work arrangements or non-linear career trajectories, while ensuring equitable access to development and promotion opportunities.

Principle 8 – Design and Human Values. The core idea here is that a primary goal of design is to ensure a high quality of work and life (e.g., in terms of autonomy, variety, continuous learning, social recognition).

Gender-aware lens. Interpreting this principle through a gender lens requires *to redefine the very concept of "quality of work/experience" by explicitly including gender equity, psychological safety, absence of stereotypes, and respect for intersectionality.* Promoting human values means placing inclusivity at the center, countering algorithmic oppression, and ensuring that every user/worker is treated as an autonomous subject with agency.

Principle 9 – Incompletion. Cherns underlines that design is an iterative process and never definitively completed: closing one option opens others and requires continuous evaluation.

Gender-aware lens. Applying a gender-sensitive view implies that *gender equity and awareness are not an end-state to be ticked off on a checklist, but a continuous process of learning, auditing, and adaptation.* As social norms, technologies, and identities evolve, the sociotechnical system must remain open to critical redesign and continuous redefinition of its gender assumptions.

4. A gender-aware view of the socio-technical hexagon

To bridge the gap between foundational principles and operational design, we move beyond the high-level theoretical formulation to examine how a gender-aware lens can be embedded within sociotechnical practice. To this aim, we refer to the socio-technical hexagonal model, introduced by Davis et al. [12] as an evolution of Leavitt's classic diamond framework [23].

Such model formalizes organizations as complex systems composed of six interdependent nodes: "*a work system will usually have a set of **goals** and metrics, involve **people** (with varying attitudes and skills), using a range of **technologies** and tools, working within a physical **infrastructure**, operating with a set of **cultural** assumptions, and using sets of **processes** and working practices*" [12]. The foundational premise of the hexagon is that system efficacy, equity, and sustainability do not rely on isolated component performance, but rather on the alignment among all nodes: a modification introduced to any single node inevitably triggers tensions and cascade adaptations across the entire socio-technical system.

To embed a gender-aware perspective into the hexagonal framework, we adopt an illustrative approach by mapping a restricted set of key seminal contributions from gender and technology studies directly onto its core dimensions. Again, our aim here is not to provide an exhaustive review of related literature nor an exhaustive reinterpretation of the hexagon, but rather to show that actionable instruments and methodologies existing in the literature can be systematically aligned with STS models.

To this aim, we singled out four literature proposals providing complementary analytical and operational lens, focusing on different levels of a socio-technical system, as summarized in Table 2. To the **Feminist Standpoint Theory** (focusing on Epistemology) and the **Data Feminism** (focusing on Power & Data) approaches already discussed in previous sections through their roots in socio-technical and critical data studies, here we juxtapose **Feminist HCI** [3] and **GenderMag** [7], which bring a more explicitly technical and practical orientation to the analysis: Feminist HCI establishes ethical-political design values (pluralism, participation, advocacy, ecology, embodiment, and self-disclosure) to characterize feminist interaction qualities, whereas GenderMag provides actionable cognitive heuristics directly applicable to software interface evaluation. Together, these four lenses bridge high-level socio-technical theory with concrete design practices. Furthermore, Data Feminism explicitly reframes privacy protection and data governance in relation to structural power asymmetries: privacy vulnerabilities disproportionately expose women to technology-facilitated gender violence [38]. A gender-aware socio-technical system must therefore treat data privacy and anti-harassment mechanisms as core structural requirements rather than optional user settings.

We want to underline that no single framework addresses all the dimensions of the socio-technical system in isolation. Instead, a convergence of these complementary frameworks is required, a finding fully aligned with foundational STS principles, which view social, technical, and organizational dimensions as inherently intertwined and co-constitutive.

Table 2
Comparative overview of reference frameworks and mapping to the socio-technical hexagon

Approach / Lens	Primary Focus	Prevalent Methodology	Socio-Technical Dimension / Relation to the Hexagon
Feminist Standpoint Theory [18-20]	**Epistemology:** Valorization of situated knowledge and the lived experiences of marginalized individuals.	Strong Objectivity; prioritizing peripheral perspectives as the baseline.	**Social dimension** (*Goal, People, Processes*)**:** Transforms user participation from passive testing into a primary source of epistemic justice and system requirements.
Feminist HCI [3]	**Ethics & Values:** Deconstruction of implicit biases in design criteria. Definition of feminist interaction design qualities.	Critical analysis, designer reflexivity, and ethical design heuristics.	**Cultural & orientational dimension** (*Culture, Goals, Technology*)**:** Redefines organizational culture and system goals.
Data Feminism [11]	**Power & Data:** Transparency, context, and challenging power hierarchies in datasets and algorithms.	Power audits, context analysis, and investigation of invisible power structures.	**Informational dimension** (*Infrastructures, Processes*)**:** Operates on data cleaning, algorithmic modeling, and workflow governance.
GenderMag [7]	**Cognition:** Identification of gender bias in problem-solving processes and interface usability.	Cognitive Walkthrough based on 5 cognitive facets (e.g., self-efficacy, risk attitude).	**Technical dimension** (*Technology, Processes*)**:** Identifies and eliminates cognitive barriers and software friction within tools.

It is also important to observe that gender dynamics do not operate in a vacuum; rather, the influence of gender-aware design is inherently moderated by the specific contextual use of ICT artifacts. Within the hexagonal framework, this context is captured through the continuous interplay among organizational culture, operational processes, and physical or digital infrastructures, ensuring that gender-aware interventions are always situated within their specific domain of application.

5. Conclusion and “Call to Action”

In this position paper, answering the "call for bravery" issued by Davis et al. [12], we moved along the vertical dimension of gender to start paving the way towards methodologies and systems able to anticipate, predict, and prevent gender-related systemic failures in socio-technical systems. Rather than viewing the digital sphere as a neutral domain, we discussed digital inclusion as a socio-technical and structural challenge. Bridging the digital gender divide requires moving toward an integrated understanding of access, usage, and meaningful

outcomes [30]. Aligning with the United Nations 2030 Agenda for Sustainable Development [36] – and specifically its Goal 5 (Gender Equality) and Goal 10 (Reduced Inequalities) – achieving true digital inclusion is not merely a technical objective, but a fundamental prerequisite for human rights, economic justice, and sustainable development. Without addressing the systemic barriers embedded in technology adoption and design, the digital transition risks reinforcing and even amplifying existing real-world structural marginalization.

To this end, we proposed a revisiting of selected milestones of the STS evolutionary trajectory to explicitly incorporate gender-aware perspectives. Rather than presenting a definitive or closed analysis and taxonomy, our goal is to offer an initial spark for a broader, collective movement toward a gender-aware STS field capable of addressing the issues highlighted by our main research question. In addressing *RQ1 (Theoretical/Systemic Baseline)*, our reinterpretation of Cherns' foundational core shows that moving beyond functional neutrality requires reframing the theoretical baseline of sociotechnical design through a gender lens. By explicitly embedding inclusive design governance, active bias mitigation, pluralistic interactions, and sustained equity over time into Cherns' framework, we aim to set a flywheel for a systemic transformation in organizational design. In response to *RQ2 (Operational /Methodological Framework)*, the gender-aware perspective applied to the sociotechnical hexagon nodes serves as a proof of concept showing how tools scattered across the literature can be systematically structured into an operational framework for practitioners. Rather than offering an exhaustive review, this mapping outlines an actionable roadmap for surveying and categorizing gender-aware technology through an operational lens. Ultimately, we encourage the STS community to further expand this hexagonal mapping, populating its dimensions with existing and emerging gender-aware critical methods, empirical case studies, and practical tools to collectively build a comprehensive, living repository for inclusive design.

The urgency of addressing this phenomenon is starkly highlighted by recent empirical literature and international indicators across all three orders of the digital divide: physical access, digital skills/usage, and meaningful outcomes. As the systematic review in [1] demonstrates, while first-level access divides remain severe in developing nations, high-income and egalitarian countries increasingly face second-level divides, where equal infrastructure does not translate into equal literacy, confidence, or usage patterns. This structural bottleneck is further corroborated by [30], whose multi-level analysis reveals that economic constraints dominate access barriers, lack of digital literacy critically hinders usage, and socio-cultural norms persistently prevent women from leveraging digital tools for career and economic empowerment.

Official data from the United Nations, UNESCO, and UN Women underscore the global magnitude of this crisis across three main dimensions: *access and usage disparities*, where worldwide 234 million fewer women than men have access to mobile internet in low- and middle-income countries [37]; *skills and educational gaps*, with UNESCO reporting an ICT skills gender gap as high as 25% across Asian and Middle Eastern nations [35], compounded by the fact that two-thirds of the world's illiterate population are women; and *labor market and sectoral exclusion*, as women represent over 20% of engineering graduates globally but only 11% of the digital workforce, less than 1% of AI applicants in Silicon Valley [29], and around 17% of ICT sector positions in the European Union [35]. Failure to address these multi-layered barriers — ranging from patriarchal family approvals, heightened privacy risks, and pervasive technology-facilitated gender violence to algorithms blind to gender realities — ensures that women remain

passive consumers rather than active creators of the digital future. Bridging the digital gender gap is definitely an urgent imperative.

In conclusion, we observe that, while this paper primarily focuses on women's inclusion as an urgent proof of concept, the theoretical foundations leveraged here — most notably *situated knowledges* and the focus on peripheral or *marginalized perspectives* — are epistemological and design tools of far broader applicability. We argue that addressing the gender divide is not an exclusive endeavor but can rather work as a **methodological catalyst** for tackling other forms of exclusion as well. The theoretical and operational frameworks required to dismantle androcentric defaults can seamlessly serve as a blueprint for identifying and addressing other intersecting digital divides, such as those based on age, ethnicity, or socioeconomic status. Ultimately, our call to action on gender is designed to generate a ripple effect, providing the STS community with a scalable blueprint to address non-binary gender identities and broader, intersecting socio-technical vulnerabilities in future community-driven iterations.

Declaration on Generative AI

During the preparation of this work, the author used Google Translator and Gemini in order to check grammar, spelling and style (e.g. for synonyms, avoiding repetition, thesaurus function). Further, the author used Google Translator to translate to English an internal report (for some parts of Sections 3 and 4) and used Gemini in order to format the list of reference according to the template. After using these tools/services, the author reviewed and edited the content as needed and takes full responsibility for the publication's content.

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