

Gender Disparity and Digital Inclusion of Female Students in Pesantren-Based Computer Science Education

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ABSTRACT

Keywords:

Gender disparity;
Computer Science
education; Self-
efficacy; Digital
inclusion; Female
student agency.

Gender disparity in Computer Science (CS) remains a persistent challenge in pesantren-based higher education institutions undergoing digital transformation. This study aims to map sociocultural barriers, analyze female students' self-efficacy, and formulate an adaptive digital inclusion strategy for female CS students at Universitas Nurul Jadid (UNUJA). Employing a qualitative case study design, data were collected through in-depth interviews with 12 key informants (comprising female CS students, faculty lecturers, and department heads), participatory observation in computing laboratories, and an analysis of academic documents from 2022 to 2024. Data were analyzed thematically using the Miles and Huberman interactive model, framed by Social Cognitive Career Theory (SCCT). The findings reveal that while female student enrollment increased from 29% (2022) to 37% (2024), their self-efficacy in advanced programming and system architecture remained low due to technological masculinity hegemony in laboratories and sociocultural gender expectations in the pesantren environment. Nevertheless, targeted interventions such as collaborative mentoring, the establishment of a female Cyber-Santri community, and supportive pedagogy significantly enhanced female students' academic confidence. This study formulates the Integrated Inclusion Framework for Pesantren-based Tech Education, a local-value-based digital inclusion model that integrates perception reconstruction, institutional support, and cultural inclusion to empower female students' agency in the modern technological ecosystem.

Article History:

Received : 19/05/2026

Revised : 23/06/2026

Accepted: 09/07/2026

Available online: 30/07/2026

Please cite this article in APA style as:

Majid, A., & Rizkiyah, A. (2026). Gender Disparity and Digital Inclusion of Female Students in Pesantren-Based Computer Science Education. *EDUNOVATION: Journal of Education and Innovation*, 1(2), 115–127.

DOI: <https://doi.org/>

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INTRODUCTION

The acceleration of the global digital economy has elevated Computer Science (CS) to a strategic discipline that determines national competitiveness within data-driven industries, artificial intelligence, and automated systems (Kubilay & Celiktas, 2025). In response to these rapid structural shifts, higher education institutions globally are reconfiguring their academic frameworks to

cultivate high-tier technical talent capable of navigating complex industrial landscapes (Dwivedy et al., 2025). Within this evolving ecosystem, mastery of CS is no longer interpreted as a specialized, isolated skill set, but rather as a foundational literacy that dictates an individual's agency and participation in modern digital society (Code, 2025) and (et al., 2023). Consequently, academic institutions face increasing pressure to foster inclusive computing environments that ensure equitable access to technological knowledge regardless of demographic backgrounds.

Mirroring these global dynamics, Islamic higher education in Indonesia particularly within pesantren-based university systems is undergoing a profound institutional transformation (Sofi et al., 2025) and (Huda et al., 2025). Historically positioned as centers for classical religious text transmission, these institutions are increasingly integrating digital competencies with ethical and religious values (Shofwani et al., 2025). Universitas Nurul Jadid (UNUJA) exemplifies this emerging paradigm by developing CS programs that synthesize traditional pesantren culture with contemporary technological demands. This synthesis fosters a dynamic dialectic between tradition and digital modernity, reframing computing technology from a potential threat to traditional norms into a strategic instrument for intellectual and social empowerment.

Despite expanding institutional access to technological education, gender disparity in CS remains a persistent structural challenge across both global and national landscapes (Jaccheri et al., 2020). Female students remain disproportionately underrepresented in core computing domains, particularly in software engineering, system architecture, and cybersecurity (Shafik, 2024). Crucially, this imbalance is rarely a reflection of cognitive or intellectual limitations, but rather a consequence of deeply ingrained sociocultural constructions that codify technology as an inherently masculine domain (Tian & Ge, 2024). Framed through Social Cognitive Career Theory (SCCT) and Bourdieu's concept of gender habitus, female students frequently navigate symbolic boundaries that undermine their domain-specific self-efficacy, particularly in advanced programming and technical problem-solving (Xu & Dieckmann, 2025).

Existing literature on gender disparities in STEM has extensively documented barriers such as imposter syndrome, lack of female role models, and competitive laboratory environments within secular university settings (Eran-Jona & Nir, 2021). Furthermore, conventional inquiries into digital inclusion frequently reduce the issue to technical infrastructure and basic digital access (Fisk et al., 2023). However, these analytical frameworks often fail to capture how religious values and community norms interact with female identity formation in technological disciplines (Seaborn et al., 2023). Consequently, a significant empirical and theoretical gap remains in understanding how female students in

faith-based, pesantren-affiliated environments negotiate their academic legitimacy at the intersection of religious tradition and technological innovation.

To address this lacuna, this study situates Universitas Nurul Jadid (UNUJA) as a critical locus to examine how female student-monks (*santriwati*) navigate perceptual barriers and construct digital agency. Within this pesantren-based environment, female students encounter a dual negotiation: confronting the technological masculinity embedded in CS learning environments while remaining grounded in the sociocultural values of their religious community. Rather than viewing religious culture as a restrictive barrier, this inquiry explores how local faith-based values can be mobilized to establish a supportive digital ecosystem that legitimizes female intellectual authority in computing fields.

Grounded in these complex dynamics, this article aims to map the perceptual barriers affecting female students' participation in CS at UNUJA, analyze their domain-specific self-efficacy, and formulate a context-responsive digital inclusion strategy. The primary theoretical novelty of this work lies in the conceptualization of the Integrated Inclusion Framework for Pesantren-based Tech Education, which harmonizes technological empowerment with local sociocultural values. By advancing this framework, the study contributes to broader academic discourse on gender equity in faith-based STEM education, demonstrating how religious higher education institutions can serve as transformative arenas for inclusive digital sovereignty.

METHOD

This inquiry employs a qualitative case study design to investigate the complex interplay of gender dynamics, domain-specific self-efficacy, and digital inclusion within a faith-based higher education setting (Hidayati et al., 2025). A case study approach is uniquely suited for this investigation as it enables an in-depth, contextualized examination of contemporary social phenomena within their real-world boundaries specifically where cultural norms, religious identity, and technical education intersect. The study was situated at Universitas Nurul Jadid (UNUJA) in Probolinggo, East Java, an institution recognized for its pioneering integration of traditional pesantren values with modern computing curricula. Informants were selected through purposive sampling to capture rich, multi-perspective insights into the academic and social experiences of female students in technological disciplines. A total of 12 key informants participated in the study, categorized into three distinct groups: female CS students across different academic cohorts ($n = 6$), faculty lecturers teaching core computing subjects ($n = 3$), and departmental administrators ($n = 3$). Inclusion criteria for student informants mandated active enrollment in the CS program for at least three semesters, ensuring sufficient exposure to advanced programming coursework and laboratory environments. To protect participant confidentiality,

code names were assigned to all informants, as detailed in Table 1.

Category	Informant Code	Role / Academic Standing	Primary Focus of Data Collection
Female Students	STU-1	3rd Year CS Student	Advanced coding experiences & peer interaction
	STU-2	3rd Year CS Student	Laboratory dynamics & group project roles
	STU-3	2nd Year CS Student	Initial self-efficacy & academic transition
	STU-4	2nd Year CS Student	Sociocultural family expectations & career goals
	STU-5	4th Year CS Student	Final project leadership & technical confidence
	STU-6	4th Year CS Student	Participation in female <i>Cyber-Santri</i> community
Faculty Lecturers	LEC-1	Senior Lecturer (Programming)	Classroom engagement & technical assessment
	LEC-2	Lecturer (System Architecture)	Gender interaction patterns in lab practicals
	LEC-3	Lecturer (Software Engineering)	Mentoring & collaborative learning strategies
Administrators	ADM-1	Department Head (CS)	Enrollment trends & curricular policies
	ADM-2	Faculty Dean	Institutional digital inclusion initiatives
	ADM-3	Head of IT Development	Community support & student organization affairs

RESULT

Gender Disparity Trends and Self-Efficacy Dynamics in Computing

Analysis of academic records at Universitas Nurul Jadid (UNUJA) from 2022 to 2024 reveals a gradual increase in female enrollment within Computer Science (CS) programs, alongside a persistent structural gender gap. As detailed in Table 1, female student representation grew from 29% (58 students) in 2022 to 37% (96 students) in 2024. While this upward trajectory indicates expanding institutional access for women in pesantren-based higher education, male students continue to constitute the clear majority (63% in 2024). Field observations indicate that despite overall growth in enrollment, female students remain significantly underrepresented in advanced technical electives such as cybersecurity, system architecture, and backend engineering.

Table 1. Student Distribution in CS UNUJA by Gender (2022–2024)

Academic Year	Male Students (n)	Female Students (n)	Total Enrollment	Female Representation (%)
2022	142	58	200	29.0%
2023	151	74	225	32.9%
2024	163	96	259	37.1%

Empirical findings demonstrate a pronounced domain-specific divide in female students' self-efficacy. While female informants expressed high confidence in interface design, database management, and data analysis, their self-perceived competence decreased sharply when encountering advanced algorithmic logic and system architecture. This divide is primarily driven by psychological hesitation and the competitive atmosphere of laboratory settings rather than cognitive limitations. As STU-1 reflected during her interview:

"When facing backend architecture tasks, I often hesitate to speak up first. Even though my logic works during individual coding assignments, the competitive energy in the lab makes me feel like live programming is naturally 'their' [male students'] domain." (STU-1, 3rd-year CS Student)

Observation of laboratory practicals further underscores this dynamic. During group assignments, male students overwhelmingly assumed dominant technical roles, such as live debugging and system demonstration, whereas female students were frequently relegated to supportive functions, including project documentation and administrative coordination. Lecturers noted that while female students consistently achieved high academic marks on written evaluations, their verbal assertion in technical spaces remained constrained by competitive laboratory dynamics. As observed by a senior programming lecturer:

"In group practicals, female students consistently submit clean, well-structured code and logic. However, during live debugging or oral presentations, male students instinctively take the keyboard and microphone, overshadowing their female peers' actual technical contributions." (LEC-2, System Architecture Lecturer).

Sociocultural Expectations and Perceptual Barriers

Fieldwork data highlight that sociocultural perceptions surrounding female career trajectories in pesantren environments heavily influence how female students experience their computing education. While families generally support higher education for women as a means of intellectual elevation, specific technical careers such as network engineering, DevOps, and systems analysis are frequently perceived through a masculine lens as requiring intense, competitive, and un-Islamic work conditions. This cultural framing creates internal ambivalence for female students negotiating their professional identities. STU-4 described this subtle tension:

"My family supported me studying CS, but relatives often ask, 'Isn't programming too stressful for a woman?' There is an underlying assumption that pesantren graduates especially women should pursue teaching or administrative fields rather than technical software engineering." (STU-4, 2nd-year CS Student)

To systematically map these perceptual barriers, qualitative data were categorized into a descriptive matrix based on thematic frequency and narrative impact across informant groups, as summarized in Table 2.

Table 2. Qualitative Matrix of Perceptual Barriers and Impact Dimensions

Analysis Dimension	Primary Qualitative Findings	Impact Level	Key Manifestation
Technical Self-Efficacy	Domain-specific hesitation in algorithm & backend system architecture	High	Hesitation to lead technical group tasks
Spatial Representation	Male dominance in IT student organizations and coding laboratories	High	Female preference for quiet, independent study spaces
Sociocultural Pressure	Family preference for 'traditionally feminine' digital or teaching roles	Moderate	Ambivalence regarding long-term software engineering careers
Academic Interaction	Passive participation in competitive verbal technical debates	Moderate	Active contribution shifted to written project documentation
Institutional Inclusion	Emerging institutional support through female-led coding circles	Low–Moderate	Growing participation in supportive peer networks

As Table 2 illustrates, the primary barriers facing female students are psychological and symbolic rather than institutional or intellectual. Faculty members emphasized that when female students are placed in non-threatening, collaborative learning spaces, their technical performance matches or exceeds that of their male peers. A department administrator noted:

"The issue is rarely about cognitive ability. Female students frequently score at the top of written exams, but their internal confidence drops when navigating competitive, unstructured technical environments dominated by male peers." (LEC-1, Senior Programming Lecturer).

Institutional Interventions and Community-Based Inclusion

In response to these gendered disparities, the faculty initiated targeted digital inclusion initiatives aimed at restructuring the computing learning ecosystem. Key interventions include the establishment of a female-dedicated technology group (*Komunitas IT Putri / Cyber-Santri*), peer-to-peer collaborative mentoring, and seminars featuring female technology practitioners. Data indicate that transition from open, hyper-competitive laboratory dynamics to structured, collaborative mentoring significantly boosted female students' confidence in executing complex coding projects. STU-6 highlighted the

transformative effect of these community spaces:

"Joining the female Cyber-Santri coding circle changed everything. Practicing algorithms in a safe, non-judgmental space allowed us to ask 'basic' questions without feeling inferior. It gave me the confidence to take on the lead backend developer role in my final capstone project." (STU-6, 4th-year CS Student)

These empirical findings demonstrate that digital inclusion within a pesantren-based institution cannot be achieved solely through affirmative recruitment. Instead, it requires a holistic architecture that combines institutional support, culturally resonant peer communities, and supportive pedagogy to legitimize female technical authority within modern digital ecosystems.

DISCUSSION

Technological Masculinity, Habitus, and the Efficacy Divide

The empirical findings from Universitas Nurul Jadid (UNUJA) demonstrate that gender disparity within pesantren-based Computer Science (CS) education cannot be reduced to a mere issue of structural access or cognitive competence. Instead, the underrepresentation of female students in live programming and backend architecture reflects the persistence of a technological habitus that reinforces hegemonic masculinity in STEM fields (Torres-Díaz et al., 2025). In the computing laboratories of UNUJA, male dominance during real-time debugging and oral presentations functions as a form of symbolic boundary, subtly signaling to female students that high-level technical authority remains a masculine domain (Heilman et al., 2024). Consequently, female students often adopt adaptive coping mechanisms such as assuming administrative and documentation roles in group capstones which further obscure their actual technical capabilities within the formal academic space.

Framed through Social Cognitive Career Theory (SCCT), the domain-specific divide in female students' self-efficacy characterized by high confidence in UI/UX design alongside pronounced hesitation in backend system architecture is an internalized outcome of social learning and environmental feedback (Rajkumar et al., 2026). Hyper-competitive laboratory dynamics act as negative verbal persuasions that erode female students' performance accomplishments, leading them to doubt their algorithmic reasoning despite earning top academic marks on written examinations (Xie, 2025). This phenomenon underscores that self-efficacy is inherently relational; when female students lack visible female role models among senior developers and faculty members, their professional career intentions in software engineering remain constrained (Oliveira et al., 2024).

Furthermore, the dialectic between pesantren cultural norms and digital career aspirations reveals a complex landscape of social negotiation. Contrary to conventional assumptions that religious environments are inherently regressive toward gender equity, the field data show that Islamic higher education provides

a supportive framework for women's intellectual mobility (Samier & Elkaleh, 2021). The primary tension arises not from theological doctrine, but from broader sociocultural expectations that associate software engineering with erratic work schedules and un-Islamic corporate cultures (Taj et al., 2020). Recognizing this distinction is critical for designing inclusion strategies that honor religious identity while dismantling outdated gender stereotypes.

The Integrated Inclusion Framework: Synthesizing Local Values and Agency

To address these multidimensional barriers, this study synthesizes empirical findings into a conceptual model termed the Integrated Inclusion Framework for Pesantren-based Tech Education, as illustrated in Figure 1. This framework asserts that sustainable digital inclusion requires a triadic alignment: Perception Reconstruction, Institutional Support, and Cultural Inclusion (Liu & Chen, 2025). Rather than treating faith-based values as obstacles to be neutralized, the framework leverages local pesantren ethics such as collective solidarity (*ukhuwah*), ethical stewardship, and intellectual perseverance as foundational assets for technological empowerment (Syauqi et al., 2025).

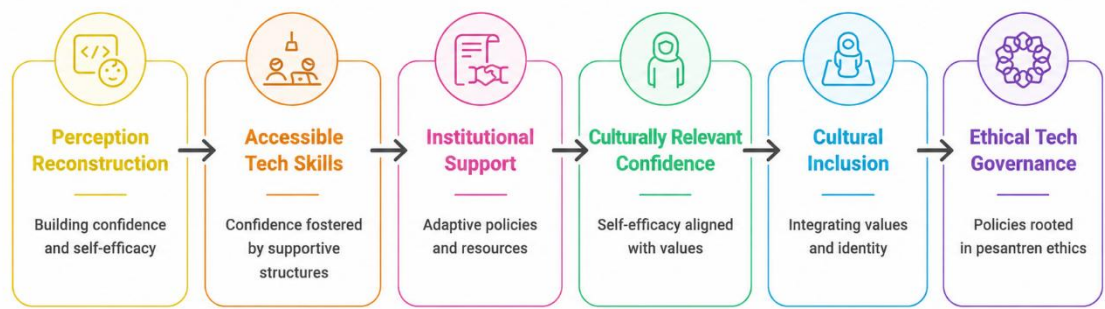


Figure 1. Structural Pillars of the Integrated Inclusion Framework

The pillar of Cultural Inclusion is particularly pivotal in fostering a hybrid identity: the Santriwati-Programmer. By embedding digital competencies within a framework of Islamic ethics and social responsibility, female students construct a legitimate identity that harmonizes spiritual devotion with digital mastery (Hairani & Conermann, 2025). This synthesis enables female students to assert their technical agency without feeling alienated from their religious heritage, effectively reframing technology from a secularized, masculine arena into an emansipatoric tool for community service.

Simultaneously, the establishment of single-gender safe spaces specifically the Cyber-Santri female technology circles serves as a vital catalyst for perception reconstruction. Within these non-judgmental, collaborative environments, female students engage in low-stakes experimentation, peer coding, and vulnerability-sharing, which directly counteracts the imposter syndrome

induced by competitive co-ed laboratories (Friday, 2025). Empirical evidence confirms that collaborative mentoring models foster higher technical self-efficacy than open-market competitive models, providing female students with the psychological resilience needed to navigate broader professional tech ecosystems (Huang et al., 2025).

Pedagogical Transformations and National Strategic Implications

The findings of this inquiry carry profound implications for the reconstruction of Computer Science pedagogy in faith-based higher education. Engineering curricula must transcend rigid, purely mechanistic instruction by incorporating humanistic, project-based learning that connects software engineering to real-world social impact (Gannar & Kilani, 2025). Moreover, institutional policies should formalize reverse mentoring and affirmative laboratory guidelines that prevent the automatic delegation of female students to non-technical project roles. By restructuring laboratory culture to reward collaborative problem-solving over individualistic assertion, academic departments can build an egalitarian learning environment that nurtures diverse technical talents (Avissar & Yondler, 2025).

In a broader national horizon, achieving digital sovereignty in Indonesia requires tapping into the intellectual potential of young women in faith-based institutions. As the global economy increasingly relies on artificial intelligence, data science, and system architecture, excluding female students in pesantren environments from high-level technical creation exacerbates structural inequality in knowledge production (Sumadi & Nurteti, 2024). The UNUJA model demonstrates that when pesantren-based universities proactively build inclusive digital ecosystems, they not only advance gender equity but also cultivate a new generation of ethically grounded female tech innovators capable of addressing complex global challenges.

CONCLUSION

This study demonstrates that gender disparity in Computer Science within pesantren-based higher education is fundamentally shaped by domain-specific self-efficacy divides and entrenched sociocultural perceptions of technological masculinity, rather than cognitive limitations. Although female student enrollment at Universitas Nurul Jadid exhibited a steady upward trajectory from 29% in 2022 to 37% in 2024, female students continue to navigate psychological hesitation and symbolic marginalization when engaging with live programming, backend system architecture, and hyper-competitive laboratory environments. The empirical evidence underscores that these internal barriers are structurally mediated by a scarcity of visible female role models and persistent social expectations that associate advanced software engineering with

masculine work cultures, thereby constraining female students' professional career agency despite their high academic achievements.

To address these systemic challenges, this inquiry formulates the Integrated Inclusion Framework for Pesantren-based Tech Education, which establishes a triadic alignment between perception reconstruction, institutional support, and cultural inclusion. By mobilizing local pesantren ethics such as collective solidarity and ethical stewardship as foundational assets, the framework legitimizes a hybrid Santriwati-Programmer identity that seamlessly harmonizes spiritual devotion with advanced technological mastery. Ultimately, restructuring computing pedagogy through collaborative peer networks, single-gender learning safe spaces like the Cyber-Santri community, and gender-responsive academic policies proves that faith-based higher education can serve as a transformative arena for inclusive digital sovereignty, equipping young women to stand as co-architects of future technological innovation without forfeiting their cultural and religious heritage.

ACKNOWLEDGMENT

The authors express their profound gratitude to the leadership and LPPM of Universitas Nurul Jadid (UNUJA) for their institutional facilitation and academic support. Special appreciation is extended to the faculty, lecturers, and students at UNUJA who generously contributed their insights and data, making this research on digital inclusion possible.

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