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# Interdisciplinarity as an Entry Point into Computer Science: Women's Pathways, Identity, and Belonging in Hybrid Higher Education

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**Abstract**. The study examines how academic interdisciplinarity influences women's engagement with STEM, building on literature showing that integrating Humanities and Social Sciences enhances critical thinking, ethical awareness, and inclusiveness in techno-scientific education. While prior research has mainly focused on institutional and pedagogical outcomes, less is known about women's lived experiences of hybrid pathways: using qualitative Thematic Analysis of interviews with nine female students enrolled in hybrid STEM programs, the findings indicate that interdisciplinarity operates as a relational process, shaping women's trajectories, perceptions of belonging, and persistence in STEM, as well as their engagement in competitive environments like Informatics Olympiads. In fact, integrated pathways make these domains more accessible, enabling the construction of new hybrid identities, and providing resources for navigating gendered environments - including highly competitive settings such as IT contests - although their effectiveness depends on institutional recognition.

**Keywords**: STEM Literacy, Interdisciplinarity, Gender-Inclusive Learning, Computer Science.

## 1. Introduction

Traditionally, techno-scientific fields have been viewed as distinct from the Humanities, grounded in the longstanding separation between empirical inquiry and the interpretative, value-laden perspectives peculiar to humanistic disciplines. This disciplinary split has reinforced the idea that STEM subjects are all about objectivity, measurement, and technical proficiency, while the Humanities' focus is on critical reflection, cultural analysis, and ethical debates. However, a growing interdisciplinary body of research underscores the benefits of bridging these domains to cultivate higher-order thinking needed to address the societal implications of scientific and technological developments (Sánchez & Martínez, 2021; Helligsø, 2023).

In fact, the multidimensional nature of twenty-first-century global challenges requires interdisciplinary approaches to problem-solving that extend beyond purely technical expertise (Scholkmann *et al.*, 2023): in this scenario, the integration of Social Sciences and Humanities perspectives into STEM education represents a significant pedagogical shift toward fostering a more holistic understanding of complex contemporary problems. These modern issues require solutions informed not only by technical expertise but also by cultural, social, ethical, and historical perspectives (Faulconer *et al.*, 2020; Clark, 2025).

It has been demonstrated that this educational approach enhances students' problem-solving abilities, communication skills, and preparedness for addressing global phenomena such as climate change and infectious diseases, complex issues that demand analyses extending well beyond conventional disciplinary boundaries (Joseph & Uzondu, 2024; Park & Cho, 2022). By bridging ethical, cultural, and social considerations into STEM curricula, such approaches not only deepen students' understanding of scientific interconnectedness but also strengthen their capacity for responsible decision-making in navigating socio-scientific challenges (Mudaly & Chirikure, 2023).

## 2. Related Work

Even though traditional STEM education provides a strong foundation in scientific and technological skills, it often falls short in cultivating the critical thinking and civic awareness required to address the long-term consequences of global changes (Lee *et al.*, 2023). An example of this is the tendency of traditional engineering pedagogy to prioritize technical efficiency over environmental, ethical, and social considerations (López-Santiago *et al.*, 2024; Cañavate *et al.*, 2025).

Hybrid educational frameworks thus diverge from traditional STEM pedagogies that prioritize objectivity and procedural knowledge while neglecting socio-cultural and philosophical concerns (Singh, 2020): by embedding moral and ethical deliberation within scientific learning and foregrounding real-world contexts, complex problems are analysed through the interplay of scientific evidence and human values (Ramos & Mendonça, 2021; Zeidler & Karışan, 2024; Roehrig *et al.*, 2021). This encourages a critical evaluation of both scientific information and its societal implications (Johnson *et al.*, 2024; Ke *et al.*, 2023), deepening students' understanding of science while enhancing their awareness of its societal dimensions (Viehmann *et al.*, 2024).

In this context, Socio-Scientific Issues (SSI) – i.e., socially relevant, controversial, real-world problems that are informed by science and often include an ethical component (Sadler *et al.*, 2007) - represent a powerful educational tool for demonstrating the social relevance of STEM subjects and therefore strengthening scientific consciousness and active citizenship (Alcaraz-Domínguez & Barajas, 2021). As a matter of fact, the contested viewpoints and the absence of clear solutions that characterize these issues imply that they cannot be resolved solely through scientific knowledge: the latter has to be blended with ethical, political, and economic considerations in order to face complex scenarios that lack straightforward answers (Lin *et al.*, 2018; Zeidler & Karışan, 2024; Högström *et al.*, 2024; Garrecht & Adler, 2025).

By requiring students to draw on evidence and to assess competing moral considerations, real-world dilemmas become vehicles for meaningful learning that highlight the social embeddedness of science, enhancing students' grasp of the nature of scientific inquiry (Gutierez, 2014; Güler, 2023; Johnson *et al.*, 2024; Kinskey & Newton, 2024). In fact, integrated education – by compelling students to confront their preconceived notions, refine their interpretations through dialogue and reflection, and integrate both scientific and moral considerations into their reasoning (Karahan, 2022; Hanifha *et al.*, 2023; Zeidler *et al.*, 2019) - not only helps them to situate scientific progress within broader social narratives, accounting for its impacts on communities (Hwang *et al.*, 2023; Lee *et al.*, 2023), but also helps them to connect scientific knowledge to everyday life. By recognizing how scientific developments intersect with ethical, social, and environmental concerns, learners develop robust critical thinking and problem-solving skills (Helligsø, 2023; Karışan & Zeidler, 2024; Bezen, 2024) that allow them to evaluate the moral nuances of contemporary technological societies (Martorell *et al.*, 2024; Turgut & Yakar, 2021; Hương *et al.*, 2024; White & Delaney, 2021).

Socio-scientific learning therefore fosters the "functional scientific literacy" (Tabak, 2016) necessary for informed decision-making in contexts where ethical and scientific dimensions are deeply intertwined (Widiyanti & Susilayati, 2023; Sjöblom *et al.*, 2023; Zeidler *et al.*, 2019; Johnson *et al.*, 2020; Lee *et al.*, 2023; Burkett, 2025). This requires a complex blend of capabilities beyond traditional disciplinary boundaries (Wajngurt & Sloan, 2019). Integrating the arts, humanities, and social sciences helps cultivate "humanistic engineers" with civic responsibility and the capacity to critically engage with the intellectual foundations of science (Lambrinidou & Edwards, 2020), leading to moral development and community engagement (Chowdhury *et al.*, 2020), and thus to a comprehensive understanding and reflective judgment (Özbek & Aslan, 2024). This integration involves more than simply adding "soft skills" to technical courses: it requires a deep transformation of the underlying value systems of higher education (Helligsø, 2023) by reframing technical problems through ethical and societal lenses (Berg & Lee, 2016). This ultimately encourages students to adopt broader perspectives (Coxon, 2021): by examining how risks and benefits are distributed and how technical and scientific practices may reinforce or mitigate inequities (Verma, 2024), students learn to identify technologies' implicit values and to provide solutions that are both technically correct and socially just (Forbes & Hoople, 2023).

Thanks to this dynamic re-configuration of STEM education as a process that integrates ethical reflection, social justice, and community engagement, it is possible to co-create more inclusive and socially responsible solutions (Lucena & Leydens, 2015) by asking questions like "Who benefits from this technology?" and "What constitutes a just outcome?". This new approach to science promotes the interrogation of power dynamics, the examination of diverse perspectives, and the prioritization of equity in technological development, putting human values at the centre of innovation (Imad *et al.*, 2023; Lim *et al.*, 2021; Nieusma, 2020). This transformative approach prepares students to be not only scientifically competent, but also ethically and culturally aware of the consequences of their actions (Gutierez, 2014; Leij *et al.*, 2021; Bezen, 2024; Kirby, 2020): this allows

them to be prepared to participate in public debates around STEM-related issues (Alcaraz-Domínguez & Barajas, 2021), responding to longstanding problems in STEM education, where ethical and social dimensions have often been marginalized (Beatty *et al.*, 2023). In particular, integrating STEM with the humanities fosters a deeper understanding of cultural, social, and historical contexts (Clark, 2025), encouraging the use of technical knowledge to address social inequities (Lee *et al.*, 2023).

This hybridization is also fundamental in rapidly evolving domains like AI, enabling students to explore ethical dilemmas in immersive environments and, when combined with mathematical modelling and multidisciplinary inquiry, strengthening interdisciplinary education and enriching learning by providing personalized feedback on students' ethical judgment (Clark, 2025). In fact, AI-based tools are able to support collaboration and critical reflection on the ethical challenges inherent to STEM disciplines (Børsen & Butkevičienė, 2023; Chen *et al.*, 2025), and case studies involving AI applications, of course, improve both AI literacy and ethical awareness (Usher & Barak, 2024). In this way, students are prepared to navigate the multifaceted implications of technological progress, fostering informed and responsible innovation (Chen *et al.*, 2025) in fields where students have traditionally relied on unstructured moral intuition (Børsen & Butkevičienė, 2023). For example, Virtual Reality tools create immersive settings for ethical decision-making (Tobías *et al.*, 2025), while adaptive tutoring systems personalize these experiences and reinforce ethical reasoning (León *et al.*, 2025; Clark, 2025). AI-powered virtual laboratories enable simulated experiments while addressing real-world ethical implications, strengthening both scientific understanding and moral deliberation (Joseph & Uzondu, 2024; See *et al.*, 2023).

By incorporating elements from the social sciences and humanities, interdisciplinary STEM pedagogies effectively demonstrate how diverse academic interests can converge, offering a more holistic learning experience. This expanded pedagogical vision resonates with a diverse student body, particularly women, who often seek broader societal relevance in their STEM trajectories. In fact, evidence suggests that interdisciplinary curricula make STEM fields more accessible and better aligned with female students' personal values and aspirations (Joseph & Uzondu, 2024). By recognizing the broader range of interests and capabilities among female students (Helligsø, 2023), female retention rates are enhanced.

In higher education, the shift toward holistic STEM education is represented by interdisciplinary academic programs (Chen *et al.*, 2023; Hitt *et al.*, 2023), which stress the interconnectedness of scientific knowledge, human values, and societal well-being (Chen & Hoople, 2018; Niles *et al.*, 2020; Chen *et al.*, 2023) by bridging disciplinary divides. Globally, universities are increasingly adopting hybrid STEM programs to address persistent gender gaps in STEM. Pedagogically, these programs often utilize project-based learning, inquiry-driven methods, and teamwork, approaches strongly associated with higher engagement and retention among underrepresented groups (Costa *et al.*, 2023). Successful initiatives such as the Technical University Dublin (TUD) model - based on empirical research that demonstrates that females do not lack skills but have a diverse profile of abilities (Ovalle Ramirez, 2025) - demonstrate that hybrid STEM programs are effective

in attracting and retaining women by recognizing broader interests, consequently reducing their perceived risk and increasing their perceived self-efficacy and outcome expectations (Aizenman *et al.*, 2022). However, scientific evidence indicates that interdisciplinarity alone is insufficient without institutional enablers, such as mentorship structures, internships, faculty training, interdepartmental coordination, scholarships, tailored program orientation, and sustained academic monitoring. In particular, academic literature identifies a set of consistent principles capable of stimulating girl's interest in STEM, and consequently counteracting the gender gap that still characterizes these subjects: the integration of "explicit relevance" through real-world problem-solving; the use of active learning and collaborative practices; strong mentorship networks; robust institutional support and long-term monitoring (Freeman *et al.*, 2014).

From a psychological point of view, the key-mechanisms involved in these virtuous processes include enhanced Utility Value, where perceived usefulness and relevance boost other aspects of a person's life, like overall performance and persistence (Wigfield, 1994; Peterson, 2000; Emerick, 1992), and social identity, which is particularly important given that early sense of STEM-belonging predicts achievement, well-being, and resilience (Rainey *et al.*, 2018). In this regard, hybrid curricula provide alternative points of entry (Watkins-Lewis *et al.*, 2022), expanding the range of identities women can envision for themselves in science and consequently reducing stereotype threat (Potter, Crispin, Dollard *et al.*, 2025).

In conclusion, a growing body of research shows that interdisciplinary programs can effectively broad the appeal of STEM, promoting a more inclusive understanding of scientific practice (Cobian *et al.*, 2024; Türkkan *et al.*, 2024): the fact that STEM domains are not seen as merely technical anymore, but as disciplines with a strong social relevance, is a pedagogical shift able to attract a more diverse student population (Romkey, 2020). By connecting scientific learning to personal and structural issues (Lee *et al.*, 2023), hybrid frameworks mitigate the feelings of alienation commonly experienced by women and minorities in conventional STEM environments (Valla & Ceci, 2014; Watkins-Lewis *et al.*, 2023): this aligns scientific pursuits with prosocial goals, which research shows are particularly salient for women and strongly influence their decisions to pursue techno-scientific careers (Miller & Withers, 2023).

However, while this outcome-oriented perspective highlights the pedagogical, ethical, and civic benefits of integrated STEM education, less attention has been paid to how interdisciplinarity operates at an individual level, particularly for women. Indeed, what remains largely underexplored is how women subjectively experience interdisciplinarity in their personal and academic STEM journeys. In particular, existing studies rarely examine interdisciplinarity as a relational and experiential mechanism through which women negotiate their positioning within STEM fields, rather than as a pedagogical feature or institutional intervention alone.

## 3. Methodology & Research Design

The present study aims to explore how interdisciplinarity shapes women's subjective pathways into and through STEM, i.e., how they live and interpret hybrid pathways over time. To do so, interdisciplinarity is not conceptualized as an abstract curricular principle, but rather as a structuring mechanism that reshapes women's relationships to STEM disciplines, identities, and institutional contexts.

Given the explorative nature of the research question and the strong focus on meaning-making, sense of identity, and lived experience, the study complements existing quantitative and program-evaluation research with a processual and relational perspective, choosing a qualitative design grounded in Thematic Analysis (Braun & Clarke, 2006; Braun & Clarke, 2021). This allows the study to build directly on prior work on inclusive STEM education while advancing a deeper understanding of how interdisciplinarity can function as a device of access, legitimacy, and persistence for women in STEM, mitigating gendered individual experiences of exclusion in male-dominated environments.

Semi-structured, in-depth interviews have been conducted with 9 female participants enrolled in interdisciplinary STEM-related courses at the Roman universities of Tor Vergata and Luiss. Interviews focused on participants' educational journeys, motivations, perceptions of interdisciplinarity, experiences within STEM environments, and reflections on gender, belonging, and future aspirations. This format allowed for both comparability across interviews and flexibility to follow issues that participants themselves identified as significant.

Data have been then analysed following the six-phase approach required by Thematic Analysis. The process has been inductive, without imposing predefined categories, in order to remain close to participants' accounts. It involved:

1. Familiarisation with the data through repeated reading of transcripts;
2. Initial coding focused on meaningful segments related to interdisciplinarity, STEM engagement, and identity;
3. Development of focused codes capturing recurring patterns;
4. Construction and refinement of themes through iterative comparison;
5. Review and naming of themes to ensure internal coherence and analytical distinction;
6. Production of thematic narratives linking empirical patterns to the research questions.

Analytic dimensions included the role of interdisciplinarity as an entry point, identity resource, and buffer against gendered exclusion. Analytical rigor was ensured through iterative coding, systematic memo writing, and ongoing comparison between cases. Reflexivity was maintained throughout the research process, with attention to the researcher's positionality and interpretive role.

## 4. Results

Three overarching themes were identified regarding how academic hybridization shapes women's engagement with STEM, capturing the role of interdisciplinary configurations as entry points, identity resources, and mechanisms for navigating gendered STEM environments.

### *4.1 Theme 1: Interdisciplinarity as a legitimate entry-point into STEM.*

Across interviews, interdisciplinarity emerged as a key mechanism enabling women's initial engagement with STEM. Rather than entering STEM through narrowly defined technical pathways, many participants encountered STEM through hybrid domains that integrated technical knowledge with social, humanistic, or applied perspectives. This interdisciplinary framing reduced the perceived distance from STEM and made technical content more accessible and meaningful. Participants often described interdisciplinary programmes as providing a "safe" or legitimate space from which to approach technical disciplines without requiring early identification with traditional STEM stereotypes. As such, interdisciplinarity served as a gateway, broadening access to STEM beyond conventional entry routes.

### *4.2 Theme 2: Hybrid Identities and negotiated STEM-belonging.*

Interdisciplinarity also played a central role in shaping participants' identities and sense of belonging within STEM. Rather than adopting singular disciplinary identities, participants articulated hybrid self-understandings that combined STEM competencies with skills and values from other fields, such as communication, ethics, creativity, and social impact. These hybrid identities enabled participants to engage with STEM while resisting narrow or exclusionary definitions of what it means to be "good at STEM". In doing so, interdisciplinarity supported alternative modes of belonging that were perceived as more aligned with participants' interests and self-conceptions. This finding highlights how interdisciplinary positioning can expand the symbolic boundaries of STEM participation.

### *4.3 Theme 3: Interdisciplinarity as a buffer against gendered exclusion.*

A third theme concerns the role of interdisciplinarity in mitigating gendered exclusionary experiences in STEM environments. Participants frequently described male-dominated contexts in which women's competence or legitimacy was implicitly questioned. In such settings, an interdisciplinary positioning provided both symbolic and practical resources for navigating exclusion. By occupying roles at the intersection of disciplines, participants were able to assert value through mediation, translation, or applied problem-solving, rather than through direct competition on narrowly technical criteria. However, the effectiveness of this buffering function depended on institutional recognition. Where interdisciplinary programmes were structurally legitimised, participants reported greater stability and confidence; where hybridity was marginalised, its protective effect was weaker.

## 5. Implications for Informatics Olympiads

The study's findings offer particularly relevant insights when applied to the context of Informatics competitions, which nowadays represent one of the most prominent environments for training and recognizing concrete technical talent within STEM.

In fact, contests are often structured around a strongly disciplinary and technical conception of the discipline, centred on algorithmic problem-solving, optimization, and individual performance. However, in light of the findings presented in this research, such a model risks reproducing some of the dynamics of exclusion and limited belonging that participants describe in more traditional STEM environments.

In particular, the first theme - interdisciplinarity as an entry point - suggests that access to technical domains can be significantly broadened when they are presented alongside social, applied, or humanistic dimensions. Informatics Olympiads, by contrast, tend to privilege early and highly selective forms of access that presuppose strong identification with an abstract, competitive paradigm of the discipline. This may constitute an implicit barrier for many female students, who, as the study shows, often develop an interest in STEM through hybrid, contextualized pathways rather than through purely technical exposure. From this perspective, one key-implication concerns the reconfiguration of entry and preparation pathways for Olympiad participation. Integrating interdisciplinary elements - such as problems embedded in social, ethical, or real-world contexts - could increase the perceived relevance and accessibility of computer science, enhancing what the literature defines as "utility value" (Wigfield, 1994; Hulleman *et al.*, 2010; Peterson, 2000). Importantly, this would not entail reducing technical rigor, but rather reframing it within concrete contexts, in line with the findings that perceived relevance plays a crucial role in female engagement.

The second theme, concerning hybrid identities and negotiated belonging, is equally significant. Informatics Olympiads tend to construct and reward a form of "excellence" often associated with speed, individual performance, and mastery of advanced technical techniques. However, the findings indicate that many women develop a sense of belonging in STEM through more composite identities that include communication skills, ethical awareness, interest in social impact, and the ability to bridge different domains. This suggests that current Olympiad formats may fail to fully recognize alternative forms of excellence. One possible direction for development could involve introducing parallel or complementary formats to traditional competitions, such as interdisciplinary hackathons, collaborative challenges, or problem sets that explicitly require integrating computer science with other domains (e.g., sustainability, public policy, or AI ethics). Such formats could legitimize a plurality of ways of "being good at computer science," thereby expanding the symbolic boundaries of participation.

The third theme - interdisciplinarity as a buffer against gendered exclusion - offers perhaps the most critical implication. Informatics Olympiads are often highly competitive and male-dominated environments, where dynamics similar to those described by participants may emerge: the need to constantly prove one's legitimacy, experiences of isola-

tion, and evaluation based on narrow criteria of competence. In such contexts, the absence of interdisciplinary dimensions may limit the symbolic and practical resources available to navigate these challenges. By contrast, incorporating interdisciplinary elements could provide additional modes of participation and recognition, enabling female students to position themselves not only as technical competitors but also as interpreters, mediators, and socially oriented problem solvers. However, consistent with this study's findings, the effectiveness of such strategies would depend strongly on institutional recognition: if interdisciplinary components are perceived as marginal or secondary to the "core" competition, their impact on belonging and inclusion is likely to remain limited.

Another important aspect concerns the role of Olympiads as early orientation devices. These competitions contribute to defining who is seen as "belonging" to computer science from an early stage, shaping academic choices and future trajectories. If, as this study suggests, interdisciplinarity expands the range of possible identifications with STEM, then a strictly disciplinary Olympiad system may inadvertently restrict these possibilities, selecting not only based on ability but also on alignment with a specific identity model.

Finally, these findings invite reflection on the fact that Informatics Olympiads are not merely mechanisms for talent selection, but also cultural environments that implicitly convey values, norms, and representations of the discipline. In this sense, even partial integration of interdisciplinary perspectives could promote a vision of computer science not only as a technical field but also as a situated, socially relevant practice open to diverse forms of participation.

In conclusion, applying an interdisciplinary lens to Informatics Olympiads does not undermine their competitive nature or technical rigor, but rather enriches their educational and inclusive potential. In line with this study's findings, this could represent a key lever for broadening access, strengthening belonging, and mitigating exclusionary dynamics, ultimately contributing to more equitable and representative pathways into STEM.

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