Breaking Barriers: Analyzing Female Leadership and Expertise in Software Systems Research

***Abstract*—Women are significantly underrepresented in software system research.**

***Index Terms*—component, formatting, style, styling, insert**

I. Introduction

Diversity boosts innovation when actively maintained and protected from stereotypes [1]–[3]. Research shows that gender-diverse teams are more efficient and bring together unique ideas, which is important for creating robust, user-centered software systems [4]–[6]. Consequently, there are ongoing efforts to build more equitable, diverse, and inclusive teams in the technology sector [7]–[9]. However, despite these efforts, the gender gap in computer science is significant [10], [11] and even more pronounced in software engineering. A 2023 survey found that only 23% of software developers are female [12]. Additionally, the UNESCO 2023 report noted that, as of 2020, women made up only 31% of researchers in science and engineering [13]. These statistics highlight that women are still underrepresented in software engineering. Therefore, a comprehensive study is necessary to (a) investigate whether women are underrepresented due to their lack of contribution to research, (b) understand their prevalence in the key areas of software system research and (c) understand whether they have restricted access to collaboration and leadership opportunities.

Researchers are increasingly interested in understanding whether gender gaps are similar in both academia and industry. While several studies have conducted research to find out the gender disparity in the industry [14]–[16], few diversity-related studies have been conducted in the software system research area [17]–[21]. For example, Cavero et al. [21] found that women's participation increased at a rate of 3.5% annually from 1960 to 2010, though this growth was primarily driven by the Human-Computer Interaction (HCI) field. Other studies also report an increase in women's research contributions, although these are often concentrated in specific regions [22]. Notably, Moldovan et al. [20] uncovered significant gender discrimination among Program Committee (PC) members in major software engineering conferences, highlighting diversity challenges in committee formation, including geographic and academic vs. industry representation. While these studies provide valuable statistics on gender representation, they do not directly address whether women's underrepresentation is due to their lack of contribution or whether women are contributing at lower rates compared to men. Furthermore, the extent of women's involvement in research studies, their collaboration dynamics, and the significance of their leadership roles may influence in lowering their overall representation.

Therefore, in this paper, we conduct an empirical study to a) investigate women's participation and leadership in software system research, b) analyze their commitment and contribution to the research work, c) identify their specialization and interest in the specific area of software system research, and d) explore their collaboration dynamics at local, national, and international levels, particularly when a woman is leading or supervising the research. First, we selected 2000 articles from the Journal of Systems and Software (JSS). After filtration, we manually recorded the authors' information, extracting their names and affiliations from each paper. We identified the gender of the authors by the provided biography in each article. Then, we manually labeled their individual contribution ratio and identified the study areas where female leadership and supervision are more noticeable. Next, we explored their collaboration dynamics in various aspects. In particular, we answered four research questions and made four major contributions.

RQ_1(*participation and leadership*)**: What percentage of software systems articles have female author(s), and how often are they the lead authors?** Cynthia ►*since we are also viewing the supervision percentage, shouldn't we modify the RQ?*◄ Assessing female authorship and leadership (i.e., lead author role and supervision role) prevalence is essential for understanding the overall gender representation in software system research. Our study revealed that, although the overall ratio of female authors is low in female-contributed studies, their presence in leading positions is relatively encouraging. However, a significant disparity exists in supervisory roles, where female representation remains limited.

RQ_2(*commitment and contribution*)**: What are the most common contributions by female authors to various aspects of research projects in software systems?** Identifying the primary contributions of female authors highlights their roles and impact within software systems research. We found that while women play significant roles in conceptualizing studies and engaging in writing-related tasks, they encounter challenges in supervisory and validation positions.

RQ_3*(specialization and interest)***: Can we identify the specific areas of software systems research where female leadership and contributions are most prominent?** Examining areas with strong female leadership and contributions provides insight into the research subdomains where women are thriving. Our analysis showed that women are still underrepresented in technical areas of software research and are more focused on human-centric studies.

RQ_4*(collaboration dynamics)***: Do female authors in software systems research collaborate more within their organization, nationally or internationally?** Understanding the collaboration patterns of female authors reveals their networking reach and engagement levels in software system research. Our results showed that female-led and female-supervised studies tend to have a balanced mix of national and international collaborations. Additionally, we found that industrial collaboration levels are similar across genders in both male- and female-led and supervised studies.

joy ►*Can we add some data (percentage or values) while answering the research questions? Wouldn't it make the answers for rich?*◄

II. Methodology

Fig. 1 shows the schematic diagram of our study methodology.

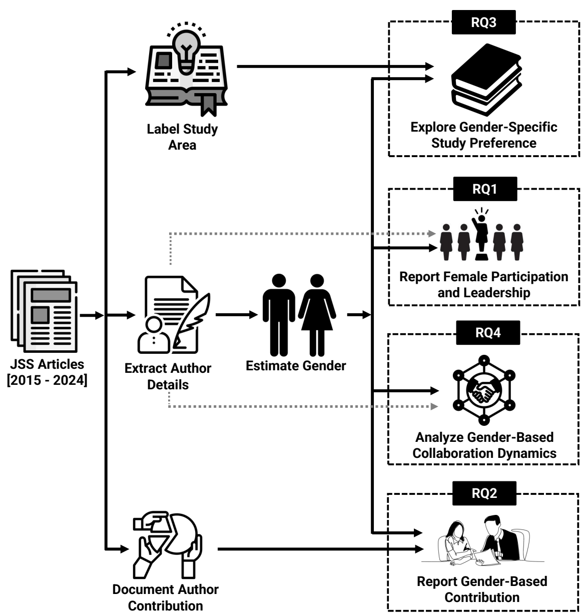


Fig. 1: Study methodology Cynthia ►*can we write estimate gender now?*◄

A. Dataset Collection

To analyze the gender-based contribution, we focused on studies that included the *CRedit authorship contribution statement* section. The Contributor Role Taxonomy (CRedit) was developed after realizing that simple-ordered author lists do not show the different types of contributions researchers make [23], [24]. Therefore, a 14-role taxonomy was introduced to represent contributions more accurately, and it has been in use since 2015 [25]. Table III summarizes the CRedit role taxonomy. To conduct our analysis, we collected 2,000 JSS articles from 2015 to 2024 and filtered them based on the availability of the CRedit section. Table I shows the breakdown of articles with and without the CRedit section. As shown in Table II, we found 763 articles with the CRedit section. Of these, only 399 articles have one or multiple female authors and among the 399 articles, 15 articles had only female authors. To analyze the collaboration pattern of both male and female authors, we discarded these 15 studies and finalized 384 articles for our further investigation.

TABLE I: Data Statistic

Year	Total articles	# of articles with CRedit
2015	181	0
2016	228	0
2017	207	0
2018	207	0
2019	174	0
2020	182	96
2021	159	123
2022	182	116
2023	236	197
2024	244	227

TABLE II: Data Criteria

Criteria	# of articles
Number of Articles (2015-2024	2000
Articles with CRedit section	763
Articles with female contribution	399
Articles with only female authors	15
Articles that have both male & female contribution	384

B. Analyzing the prevalence of the authors

First, we recorded each author's name and affiliation for every article. Next, we identified the authors' genders by reviewing the biographies provided at the end of each article. We then analyzed the prevalence of male and female authors and looked at their leadership and supervisory roles. Specifically, if a female author was listed first, we labeled it as a female-led study; if a female author held a supervisory role, we labeled it as a female-supervised study, and we applied the same approach for male-led and male-supervised studies. However, to examine the collaboration dynamics for male and female authors in **RQ_4**, we focused on studies with only one gender in the supervisory role. Out of 384 studies, we found that 163 articles had both male and female supervisors, while 221 articles had either a female or male supervisor (45 female-supervised and 176 male-supervised). To focus on how collaboration dynamics change based on a single-gender supervisor, we excluded those 163 articles with both male and female supervisors.

C. Analyzing commitment and contribution of the authors

We manually analyzed the CRediT section in each article to see which roles each author contributed to. There are 14 different roles an author could contribute to (See Table III) in each paper. For example, if an author participated in *Conceptualization (C1)*, we assigned 1 to indicate their contribution; if they did not participate, we assigned a 0. Specifically, we calculated the contribution ratios for male and female authors by taking the number of male or female authors who contributed to a role and dividing it by the total number of male or female authors in each paper.

For a given paper, P_i, where $i = 1, 2, 3, ..., K$ and K is the total number of papers, if M_i represents the number of male contributors for a specific role and M_K represents the total number of male authors in the paper, the male contribution ratio CR_{male} for that role is given by:

$$CR_{male} = \frac{M_i}{M_K}$$

TABLE III
Contributor Roles Taxonomy Details [23], [24]

ID	Contribution	Description
C1	Conceptualization	Refining the core ideas, establishing the research objectives, and outlining the overall direction or goals of the study.
C2	Data Curation	Managing activities to produce metadata, scrubbing data, and maintaining research data for initial use and later re-use.
C3	Formal analysis	Applying statistical, mathematical, computational or other formal techniques to investigate study data.
C4	Funding acquisition	Securing financial support for the project leading to this publication.
C5	Investigation	Carrying out research and investigation, specifically performing experiments or collecting data/evidence.
C6	Methodology	Developing or designing the methodology and creating models.
C7	Project administration	Managing and coordinating the planning and execution of research activities.
C8	Resources	Providing study materials, reagents, samples, patients, laboratory samples, animals, instruments, computing resources or other analytical tools.
C9	Software	Programming and software development, including designing programs, implementing code and algorithms, and testing existing code components.
C10	Supervision	Providing oversight and leadership for research planning and execution, including mentorship outside the core team.
C11	Validation	Verifying the replication and reproducibility of results, experiments, and other research outputs, either as part of the activity or as a separate process.
C12	Visualization	Preparing, creating, and presenting the published work, with a focus on visualization and data presentation.
C13	Writing - original draft	Preparing, creating, and presenting the published work, specifically by writing the initial draft, including any substantive translation.
C14	Writing - review & editing	Preparing, creating, and presenting the published work by original research group member, specifically through critical review, commentary, or revisions, including pre- and post-publication stages.

Similarly, for female contributors, if F_i represents the number of female contributors in a specific role and F_K is the total number of female authors in the paper, the female contribution ratio CR_{female} for that role is:

$$CR_{female} = \frac{F_i}{F_K}$$

For example, if a paper has a total of two female authors and five male authors, one out of two female authors has contributed in a particular role, and two out of five male authors participated in that role, then the female contribution ratio is $CR_{female} = \frac{F_1}{F_2} = \frac{1}{2} = 0.50$ and the male contribution ratio is $CR_{male} = \frac{M_2}{M_5} = \frac{2}{5} = 0.40$. Then we analyzed the quartiles of these contribution ratios by creating box plots to visualize the distribution of contributions.

D. Identify key areas of software systems with authors' leadership and contribution

joy ►Here leadership means supervisor role◄ joy ►Here contribution means first author or leadership roles. joy ►This is contradicting and the terminology is not consitent. I think we need to discuss and come up with something. And also change RQ3◄ ◄

We used open coding to manually identify the subdomains of SE where female contribution and leadership are more prominent and those where they are less present. To achieve this, we compiled a set of 384 research articles that feature at least one female author

Cynthia ►this is repetition. Also, write in past tense. joy ►I deliberately repeated this sentence to make it easier for the reader to avoid looking for the sample size on which open coding was done and why it was chosen. - We can discuss further◄ ◄

The first two authors collaboratively labeled each selected article based on its title, abstract, and keywords. They used open codes that reflect the study's focus. For example, they categorized the study by Zhu et al. [26] using labels like "testing techniques" and "code quality and maintenance" because the study closely concentrated on these areas. To be specific, the study aimed to offer guidelines for developers to help them make informed software maintenance decisions when faced with low mutation test scores. Similarly, they labeled all 384 articles manually, and when disagreements arose during coding, we discussed the issues until we reached a consensus.

Consequently, a coding book was developed that included 107 labels. These labels were then organized into broader categories. For example, labels like "AI Safety and Ethics," "AI in Testing and Bug Detection," and "AI in Development Tools" were grouped under the main area of "Applied AI in Software Engineering." This approach is similar to the one used by Sagdic et al. [27]. As a result, we identified a total of 23 subdomains within software systems.

After our initial round of coding, we identified that software system research in the JSS can be categorized into 13 subdomains[1], which closely resemble those in our codebook. To align with their framework, we first merged several of our subdomains and subsequently renamed them. For instance, the JSS subdomain titled "Methods and tools for software requirements, design, architecture, verification and validation, testing, maintenance, and evolution" is quite broad. We combined our three main subdomains—"Software Architecture and Design," "Software Quality and Testing," and "Software Maintenance and Evolution"—into this single category. This approach of integrating our identified subdomains with JSS's established subdomains ensures that our categorization is closely aligned with the journal's focus and accurately represents the recognized areas within software system research.

E. Exploring the collaboration dynamics of the authors in software system research

We recorded each author's country and institution based on their affiliations to see whether the study involved local, national, or international collaboration. For instance, if all authors were from the same institution, we labeled it as a *local collaboration*. We measured the collaboration patterns across all articles. Then, we looked specifically at studies led or

[1]https://www.sciencedirect.com/journal/journal-of-systems-and-software/about/aims-and-scope

supervised by female authors and compared these patterns with those led or supervised by males. Additionally, we checked whether the institutions were academic or industrial to gain more insights into the nature of these collaborations.

III. Participation and Leadership of women in Software System Research (RQ_1)

This section summarizes the participation, leadership, and supervision skills of women in software system research. As shown in Fig 2a, half of the total articles have one or multiple female authors, whereas 47.71% articles have no female authors at all, and a very lower number of articles (15 out of 763) have only female authors. While a slight majority of articles feature female involvement, the fact that nearly half of the studies lack female participation points to a steady imbalance. We further investigated deeper into the subset of 384 articles that include both male and female authors to check the gender representation in these studies.

Fig. 2b shows the pie chart distribution of the total male and female authors. We found the ratio illustrating a low presence of females in software system research. Out of 1,771 total authors in 384 articles, only 580 authors are female, and 1,191 authors are male.

We further analyzed the ratio of female-led and male-led studies in those 384 articles. Fig. 2c reveals that although male-led studies dominate at 58.07% (223 out of 384 articles), female-led studies are not far behind, making up a noteworthy ratio of 41.92% (161 out of 384 articles). This suggests that women are becoming more visible in leadership roles when both male and female authors are included.

Next, Fig. 2d summarizes the supervision roles of both male and female authors. We found that 25.34% (147 out of 580) of female authors hold supervision roles, whereas male authors participation in supervision role is 32.41% (386 out of 1191). This lower percentage of female supervisors indicates that women are less represented in senior supervisory positions, which may affect mentorship and opportunities for female researchers to develop their careers further.

We found similar results in previous research by Roebuck et al. [28], which shows that women are still underrepresented in supervisory roles within organizations. This low representation may be influenced by factors such as males perceiving that female leaders are less effective than their male counterparts. Additionally, Roebuck et al. found that male subordinates tend to rate female supervisors lower, while female subordinates rate male supervisors more favorably.

Summary of RQ_1: Over 45% of studies lack female authors, and the overall ratio of female authors remains low. Although over 40% of studies have female authors in lead positions, the presence of female authors is below 30% in supervisory positions.

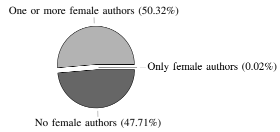
IV. Female authors commitments and contributions (RQ_2)

The findings in Fig. 3 illustrate notable patterns in female authors' involvement in contribution roles. We excluded the funding acquisition and resources roles from the figure as participation from both male and female authors in these roles is minimal but not zero. Specifically, 343 out of 384 studies had no female authors contributing to funding acquisition, and 312 out of 384 studies had no female authors involved in resource-related tasks. Similarly, 278 studies lacked male contributors in funding acquisition, and 297 studies had no male authors in the resources role. This suggests that both male and female authors contribute very little to funding and resource management tasks, with these roles mostly handled by very few individuals considered outliers.

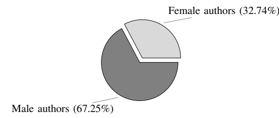
Our further analysis reveals that women's contributions are notable, particularly in conceptualization, writing the original draft, and reviewing it. For example, in at least half of the research articles, a higher proportion of female authors (78%) participated in conceptualization compared to male authors (50%). Similarly, in the role of writing the original draft, female authors are slightly ahead of male authors, with 50% of female authors and 40% of male authors contributing in at least half of the articles. This result suggests that female authors are more actively involved than their male counterparts in particular roles, such as defining the study's goals and contributing to writing tasks (drafting and reviewing). A similar pattern was observed in a study on top economics journals by Hengel [29], which found that female economists often excel in writing clarity, surpassing men in this area.

On the contrary, female participation sharply declines in supervision and validation roles. In at least half of the articles, female authors did not contribute to either of these roles at all, while male authors contributed in supervision and validation roles at rates of 33% and 25%, respectively. This result indicates a significant gender gap in supervision and validation roles, with female authors being much less involved in these areas compared to male authors. Such a disparity suggests that women may face barriers to getting into key decision-making positions, which could limit their professional growth in research. Similarly, Lindahl et al. [30] found that men often produce more research output than women during and after doctoral studies. Since women are less often involved in supervision and validation, they may have fewer chances to co-author with senior researchers and build strong networks.

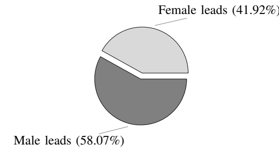
Summary of RQ_2: The results imply that while female authors are essential contributors to refining the core ideas, establishing the research objective, and also contributing to preparing, creating, and presenting the published work, they are still underrepresented in roles typically associated with providing project oversight, leadership for research planning and verifying the research outputs.



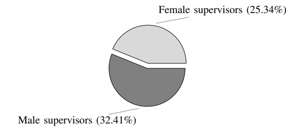
(a) Ratio of publications with one or more female authors, only female authors, and no female authors



(b) Ratio of total female and male authors in female-contributed articles



(c) Ratio of female-led and male-led studies



(d) Ratio of female-supervised and male-supervised studies

Fig. 2: Comparison of different ratios across publications and author roles

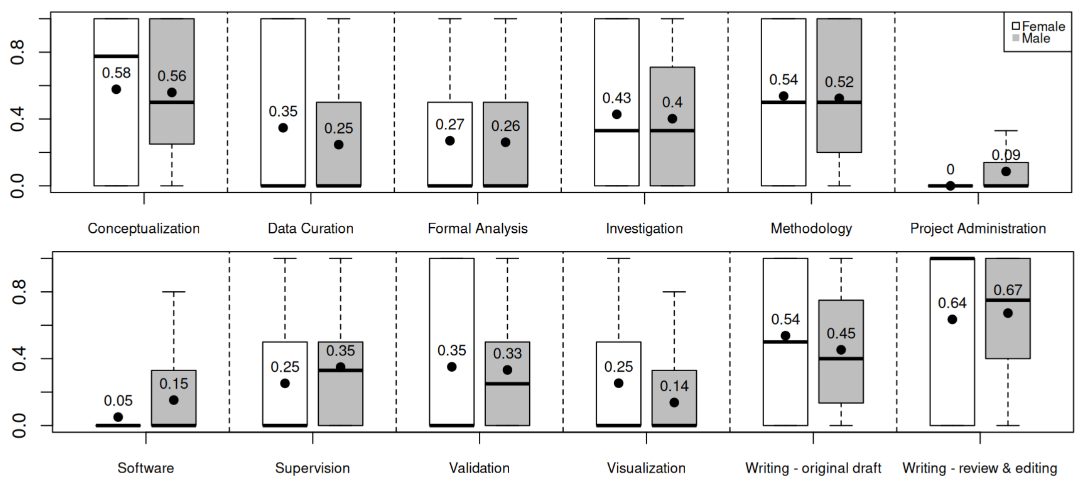


Fig. 3: Contribution Ratio

V. Female Leadership and Contribution Across Key Areas (RQ$_3$)

Our analysis identifies trends in software system research, highlighting key areas where women excel and where they fall behind men. A quantitative comparison in Table 4 shows that men-led studies outnumber women in the key areas of AI, data analytics, and big data in SE (*S5*). Specifically, 22.4% of men-led studies were in *S5*, while only 12.4% of women-led studies fell into this category. Furthermore, our Chi-Square analysis also yielded a surprising outcome—a statistically significant disparity ($p = 0.018$) specifically within the subdomain of *S5*. Interestingly, no other major areas in software system research exhibited such a gender-based difference. This trend is concerning; first-authored studies by women in AI for SE are significantly lower than those by men, highlighting the scarcity of female leadership in the most progressive sector of SE.

Conversely, we found that women are leading the majority of research in the key area of human factors and management in software development (*S4*), with 33.3% under female supervision compared to just 10.8% for male supervision. Furthermore, we have identified a statistically substantial difference ($p = 0.0005$), specifically in the *S4* subdomain. Once again, no other major areas in software systems exhibit such a significant gender-based difference in supervision. Cavero et al. [21] also found that women are indeed more engaged in human-centered areas of computer science, and this pattern seems to extend into research on software systems. This trend may stem from historical perceptions that women are more skilled in "people-oriented" joy ▶*Maybe I need to change the terminology or break down what people oriented actually means*◀ roles [31], [32], which may have influenced their research choices toward human-centric studies rather than technical fields like AI.

Summary of RQ$_3$: The results indicate that female first authors are less common than male authors in the most progressive area of software system. However, women faculty supervise research on the human aspects of software more than their male counterparts. This suggests that while men dominate technical advancements, women contribute in understanding the social implications of these technologies.

VI. Collaboration Dynamics of Women in Software System Research (RQ$_4$)

Fig. 4 highlights the collaboration pattern for all 384 studies. We found that over 50% (209 out of 384) of the articles have international collaboration. In contrast, the ratio of local collaboration is notably lower while over 40% of articles have local collaboration. Since we aim to explore how female participation can influence these collaboration patterns, we

TABLE IV: Gender-Based Leadership and Supervision of Articles in Key Areas of Software Systems Research joy ►I need to fix the table with total number of articles and percentage◄

ID	Key Areas	% Female Led	% Male Led	% Female Sup	% Male Sup
S1	Methods and tools for software requirements, design, architecture, verification and validation, testing, maintenance and evolution	23.6	28.7	20.0	26.1
S2	Agile, model-driven, service-oriented, open source and global software development	5.0	4.5	0	7.4
S3	Approaches for cloud/fog/edge computing and virtualized systems	6.8	6.3	4.4	5.1
S4	Human factors and management concerns of software development	17.4	13	33.3	10.8
S5	Artificial Intelligence, data analytics and big data applied in software engineering	12.4	22.4	15.6	23.9
S6	Metrics and evaluation of software development resources	0	0.9	0	0
S7	DevOps, continuous integration, build and test automation	3.1	0.4	2.2	1.7
S8	Business and economic aspects of software development processes	1.9	1.3	0	0.6
S9	Software Engineering education	4.3	2.7	6.7	1.1
S10	Ethical/societal aspects of Software Engineering	1.9	0.4	0	0.6
S11	Software Engineering for AI systems	1.9	0.9	4.4	1.7
S12	Software Engineering for Sustainability	1.2	0	0	0
S13	Methods and tools for empirical software engineering research	20.5	18.39	13.3	21.0

further investigated the collaboration pattern when female authors are in the lead or supervisory position.

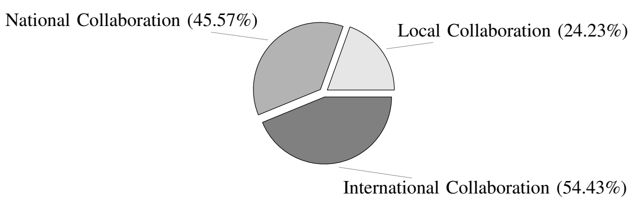


Fig. 4: Collaboration dynamics of all the studies

Fig. 5 illustrates the collaboration dynamics for the female-led and male-led studies. We found that the overall collaboration ratio of female-led studies is lower than males. However, Female-led studies show a relatively balanced distribution among the three types of collaborations. Over 40% female-led studies involve both national and international collaboration, with national collaboration being slightly more common. Meanwhile, local collaborations are also at a similar level (37.63%). This distribution suggests that female-led research teams tend to engage in a balanced mix of collaborations across different levels.

In contrast, male-led studies show a higher dependence on local collaboration which significantly surpasses the national and international collaboration (ranging from 57.14% to 58.85%). The higher percentage of local collaborations in male-led studies suggests that male-led teams tend to focus more on collaboration with nearby researchers, while female-led teams seem to extend their collaborations more evenly across national and international levels.

Fig. 6 and Fig. 7 illustrate the collaboration dynamics for the female-supervised and male-supervised studies. As outlined in II-B, we included only those articles where supervision was solely by one gender. For female-supervised studies (Fig. 6), international collaboration stands out, accounting for 53.33% (24 out of 45 articles joy ►Here, 45 has no context as a reader, might be hard to comprehend if the reader is scanning or skimming◄). This indicates that female-supervised research

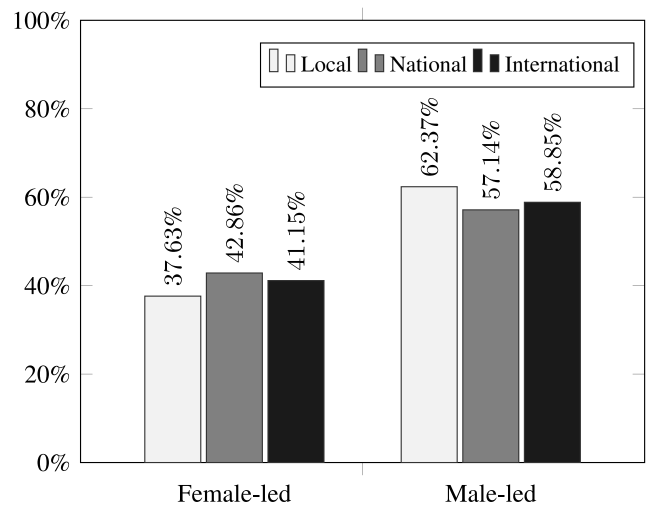


Fig. 5: Collaboration dynamics of female-led and male-led studies

teams often extend their work beyond national boundaries. A lower percentage of local collaboration, i.e., 33.33% (15 out of 45 articles), compared to national collaboration, i.e., 46.67% (21 out of 45 articles), suggests that female-supervised teams prefer to collaborate on a global scale rather than local networks. In comparison, the male-supervised studies (Fig. 7) show a significantly lower percentage of local collaboration, which makes up only 25.00% (44 out of 176 articles) of the total. Whereas the national and international collaborations are relatively balanced, with 46.30% (87 out of 176 articles) at the national level and 50.57% (89 out of 176 articles) at the international level. Overall, both male and female-supervised studies show higher engagement in international collaborations, though female-supervised studies highlight a slightly higher global reach. This finding supports Aksnes et al.'s [33] insights on international collaboration, highlighting how a research field can shape the likelihood of working across borders. For instance, female researchers often lead studies in human factors and management—areas (See Section V) where understanding different human perspectives is crucial. This focus may drive them to seek global collaborators to enrich their research with varied viewpoints in these fields.

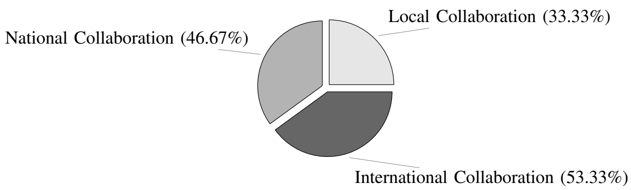


Fig. 6: Collaboration dynamics of female-supervised studies

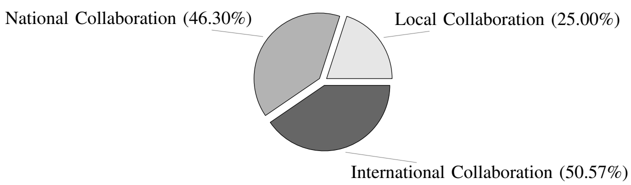


Fig. 7: Collaboration dynamics of male-supervised studies

We further explored collaboration types at the industrial and academic levels. Both female-led and female-supervised studies show a similar level of industrial collaboration: 24.84% (40 of 161 studies) and 26.67% (12 of 45 studies), respectively. Interestingly, male-led and male-supervised studies follow the same trend, with 25.11% (56 of 223 studies) and 25.57% (45 of 176 studies) involving industry collaboration. This similarity across both female and male leadership types highlights a consistent preference for industrial partnership, regardless of gender.

Summary of RQ$_4$: Although there are differences, both male-led and female-led studies contribute significantly to national and international collaborations. However, the notably lower percentage of female-led local collaboration indicates that female-led teams are more likely to work with researchers from outside their local region. Similar results can be seen in female-supervised studies that show a higher percentage of international collaboration compared to male-supervised studies. Interestingly, the remarkably lower percentage of male-supervised local collaboration indicates that male-supervised studies focus more on national and international collaborations, while female-supervised studies maintain a more balanced approach. Moreover, industrial collaboration levels show a consistent pattern across genders in both male and female-led and supervised studies.

VII. Literature Review

Several studies have been conducted to analyze diversity in the context of software engineering research, and many have highlighted that very few diversity-related studies have been conducted in the academic area [9], [17]–[20], [22], [34]–[36]. For instance, Cavero et al. [17] conducted a study analyzing computer science publications from 1936 to 2010 to examine the evolution of women's involvement in computing research. The study revealed that women's participation in computer science research grew at a compound rate of 3.5% from 1960 to 2010. It also found that women are particularly active in the Human-Computer Interaction field. Similarly, Boekhout et al. [18] conducted a large-scale bibliometric analysis of gender differences across scientific disciplines. They found that the percentage of women starting research careers increased from 33% in 2000 to 40% in recent years. However, men produce 15-20% more publications than women, and in biomedical fields, men are 25% more likely to be the last author, indicating more senior roles for men. In another study, Bano and Zowghi [19] conducted a qualitative study examining gender disparity in key roles (general chair, program chair, and main track PC members) at six top SE conferences over ten years. They found significantly fewer women in these top roles and observed that having a female general chair or PC chair does not necessarily lead to increased participation of women in other visible organizational roles. Felizardo et al. [22] found that research contributions from women in secondary studies have globally increased over the years but are still concentrated in European countries. In contrast, Santana et al. [35] noted that women remain a minority in academia despite efforts to highlight female success in computing. Their study focused on the presence of women at Brazilian Computer Society Congress events. Considering works published, women stand out in almost 60% of them, even constituting only 31% of the relevant quantitative role of authors in the development and scientific progress of computing. Maldovan et al. [20] analyzed the diversity of program committee members in three major Software Engineering conferences (ASE, FSE, and ICSE) from 2019 to 2023, focusing on gender, geography, seniority, continuity, and industry/academia affiliation. Their study revealed a significant gender disparity. At ASE, 75.3% of chairs and committee members were male, 24.3% female, and 0.4% non-binary. For ESEC/FSE, the male percentage was 65.2%, female 33.6%, and non-binary 1.2%. ICSE showed the smallest gender gap, with 61.7% male, 37.6% female, and 0.7% non-binary representation. Hosseini et al. [36] conducted a quantitative analysis comparing male and female researchers at Dublin City University. From 2013 to 2018, they found that women had fewer publications, received fewer citations, and participated less in international collaborations. Perez et al. [9] conducted a systematic literature review of 131 diversity studies in the SE industry and OSS development, highlighting strong biases against women, particularly in gender, age, race, and nationality dimensions. Recently, Oliveira et al. [37] conducted a cross-sectional survey to explore women's experiences transitioning from academia to the software industry. Their study identified several challenges faced by women, including impostor syndrome, invisibility, exclusion from decision-making processes, and distrust. Finally, Narayanan et al. [34] conducted a systematic quantitative analysis of diversity in publications and program committees of top Software Engineering conferences and journals. Their study revealed biases and entry barriers related to ethnicity, gender, and geographical location. One key finding showed that in ACM TOSEM 2019 and IEEE TSE 2012, articles with female first authors had a higher chance of receiving more citations, although this trend did not hold statistically for other years.

Moreover, the lack of diversity in the Artificial Intelligence (AI) research field has been a growing concern, and Freire et al. [38] found out that women are more present in organizing committees than as authors. Moreover, in order to monitor diversity in the AI research community, the *divinAI* (Diversity in Artificial Intelligence) project[2] started in 2019, and their studied data reflected the low presence of women in the AI field [39]. Even when women are engaging in AI research, a study conducted by Stathoulopoulos and Mateos-Garcia [40] indicates that a significant number of women AI researchers tend to focus on or contribute actively to research related to societal issues (such as ethics, social impact, or policy related to AI), rather than purely technical domains. Their study derived from the large-scale analysis of gender diversity in AI research using publications from *arXiv*.

Therefore, there remains a research gap to further analyze the detailed insight into the contributions of female authors, specifically in software system research. Additionally, no studies have thoroughly analyzed diversity across different areas within this field. Our study fills this gap by analyzing the specific contributions women are making in research work and investigating the impact of collaboration when research is led or supervised by a female.

VIII. Threats to Validity

Threats to external validity relate to the generalizability of our findings. We chose JSS articles because it's the only software engineering journal that includes a special section listing each author's contributions. By analyzing all articles published in JSS since the introduction of CRediT, we ensured comprehensive coverage for this journal. However, our conclusions may not apply to research in other fields, where author contributions might be recorded differently.

Threats to internal validity relate to experimental errors and biases. include potential inaccuracies in gender prediction. We recognize that our manually categorizing key areas in SE could be subjective. To address this effectively, the first two authors collaborated to code each article, grouping these codes into common themes and discussing disagreements. After our inductive coding, we aligned our themes with established key areas from the JSS to ensure consistency with recognized SE domains.

Another challenge to internal validity is the use of a binary approach to gender detection. Our method only identifies male or female genders, excluding other gender identities, such as non-binary individuals. We acknowledge this limitation and suggest that future studies use more inclusive methods that recognize non-binary and other gender identities for a broader and more accurate analysis.

[2]https://ai-watch.ec.europa.eu/humaint/divinai_en

IX. Conclusion

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