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

***Abstract*—This document is a model and instructions for LaTeX. This and the IEEEtran.cls file define the components of your paper [title, text, heads, etc.]. *CRITICAL: Do Not Use Symbols, Special Characters, Footnotes, or Math in Paper Title or Abstract.**

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

I. Introduction

SM ►***First paragraph.***
– Introduce diversity – Why is diversity important? – Slightly introduce the essence of our study◄

SM ►***Second paragraph.***
– Summarize the existing attempt – Explicitly mention the research gap – Re-state the essence of our study more boldly◄

SM ►***Third paragraph.***
– State - what is this study for – What we are doing (methodology & goal)◄

Diversity boosts innovation and improves results when it is actively maintained and protected from stereotypes [1]–[3]. Gender-diverse teams not only work more efficiently but also bring together unique perspectives that improve problem-solving capacity and create better work environments [4], [5]. Having women in all-male group can introduce new viewpoints and strategies, which contributes to the group discussions and decisions [6]. Despite these advantages, women remain significantly underrepresented in all sectors. For instance, Artificial Intelligence (AI) is a fast-paced industry and has a significant high societal impact, but globally only 14% of AI researchers are women [7]. Moreover, the lack of representation of women in this industry has resulted in lower-quality AI products [8]. This underrepresentation limits women's career and skill development opportunities [9]. While software organizations have initiated efforts to promote diversity and inclusion—such as the Linux Foundation's Software Developer Diversity and Inclusion project [10], [11], therefore, it is important to investigate if the dynamics of diversity have changed in the field of software systems research with the initiated efforts or if women are still underrepresented.

Several existing studies investigated the diversity in software system research, highlighting that few diversity-related studies have been conducted in the software research area [12]–[19]. According to the literature, women's participation in computing research has both shown growth [12], [13] and faced consistent challenges [14], [15]. For example, Cavero et al. [16] found that women's participation grew at a compound rate of 3.5% from 1960 to 2010, particularly in the field of Human-Computer Interaction. Similarly, Boekhout et al. [13] observed that the percentage of women starting research careers increased from 33% in 2000 and 40% in recent years. On the contrary, Bano and Zowghi [14] identified significant gender disparities in key roles at top Software engineering conferences. They also noted that female leadership does not necessarily increase women's participation in other organization roles. In particular, Moldovan et al. [15] revealed significant gender discrimination among Program Committee members in major software engineering conferences. Other studies have found that women's research contributions are increasing but remain concentrated in certain regions [17], and that gender disparities exist in academic productivity and collaboration [18], [19]. Despite these insights, there remains a lack of focused research investigating women's specific contributions to software systems research and how the dynamics of diversity impact their leadership roles and collaboration within the field.

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 select 1,005 articles from the Journal of Systems and Software (JSS) because only this journal contains a separate section to provide an overview of the contribution each author made. After filtration, we manually recorded the authors' information, extracting their names and affiliations from each paper. We utilized the GPT-4 model to predict their gender and validated these predictions against the author descriptions provided in the articles. Then, we manually labelled their study areas and documented their specific contributions. In particular, we answer these three research questions through three 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?

We investigate women's participation in software system research and try to find out the percentage of publications that have women in leading positions. We record the number of female authors of a publication and also record whether any publication has a woman as the first author. **Result?**

RQ$_2$(*commitment and contribution*)**:** What are the most common contributions by female authors to various aspects of research projects in software systems? In this research question, we want to analyze the how women are contributing in the research work by investigating their specific contributions. We extract their contribution list from each paper and record them to analyze the most common contributions made by female authors. **Result?**

RQ$_3$*(specialization and interest)***:** Can we identify the specific areas of software systems research where female leadership and contributions are most prominent?

grounded theory gender-wise report to see females are participating more in which research area

RQ$_4$*(collaboration dynamics)***:** Do female authors in software systems research collaborate more within their organization, nationally or internationally?

We attempt to explore whether female authors in software system research collaborate more in institutional, national and international levels. We also want to investigate the scenario of collaboration when the research was led or supervised by females. **Result?**

II. Literature Review

Several studies have been conducted to analyze the diversity in the context of software system research and many have highlighted that very few diversity-related studies have been conducted in the academic area [12]–[15], [17]–[21]. For instance, Cavero et al. [12] conducted a study analyzing computer science publications from 1936 to 2010 to examine the evolution of women's involvement in computing research. They focused on computing conferences and journals, analyzing women's participation as authors and their productivity, and comparing their average research careers to those of men. 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. [13] 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 [14] 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. [17] 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. [18] 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, a major concern in Latin America. However, 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. [15] 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. [19] 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. [21] 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. Finally, Narayanan et al. [20] 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.

Several studies have also been conducted to analyze the diversity in the context of industry and open-source software projects [9], [11], [22]. Zolduoarrati et al. [22] showed that there is evidence suggesting females are often underrepresented in the software engineering community. They tried to better understand gender differences in the Stack Overflow community in order to delineate the value of gender diversity in the field of software engineering. Their result indicated that female contributors on Stack Overflow differed significantly from males in relation to their orientation, attitudes, and knowledge-sharing patterns. Similarly,Trinkenreich et al. [9] found that women are underrepresented in Open Source Software (OSS) projects, leading to missed career opportunities for women and a lack of diverse perspectives for the projects. They reviewed 51 articles (2000-2021) on women's participation in OSS, finding that women account for only 5% of core developers and less than 5% of pull requests, though their pull request acceptance rates are similar or higher than men's. Women contribute both code and non-code work, motivated by skill development, altruism, and kinship, but face social challenges like lack of peer parity and non-inclusive communication. Efforts to promote diversity in software development have increased in the last decade. The push for increased diversity in software has been supported publicly, through annual diversity reports by some of the world's most visible companies, such as Microsoft, Google, and Facebook, as well as through large projects like the Linux Foundation's Software Developer Diversity and Inclusion project [10], which explores, evaluates, and promotes best practices from research and industry to increase diversity and inclusion in software engineering [11]. Kazmi [23] and Maheshwari [24] also emphasize that women in both academia and industry, despite their impressive performance, face work-life balance issues and impostor syndrome. However, they can be supported by mentorship, which helps them overcome challenges and advance in their careers [24].

Moreover, the lack of diversity in the Artificial Intelligence (AI) research field has been a growing concern, and Freire et al. [25] found out that women are more present in organizing committees than as authors due to the fact that those conferences are as well balancing gender among organizers, for instance. Moreover, in order to monitor diversity in the AI research community, the **divinAI** (Diversity in Artificial Intelligence) project[1] started in 2019, and their studied data reflected the low presence of women in the AI field [26]. Even when women are engaging in AI research, a study conducted by Stathoulopoulos and Mateos-Garcia [27] 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*.

However, despite these efforts, there is still a lack of 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.

III. Methodology

A. Dataset Collection

We found that the Contributor Role Taxonomy (CRedit) was developed after realizing that simple-ordered author lists do not show the different types of contributions researchers make [28]. Therefore, a 14-role taxonomy was developed to capture contributions more accurately, and it has been in widespread use since 2015 [29]. According to the official website [28], the taxonomy description is summarized in Table III. We discovered that only JSS includes a *CRedit authorship contribution statement* section in each article, highlighting each author's role. So, we focused only on JSS publications and collected 2,000 JSS articles from the years 2015 to 2024. We filtered the articles based on the availability of the *CRedit* section. Table I shows the number of articles with and without the contribution section. Finally, we found 763 articles with a section on contribution (Table II. Among them, only 399 articles have one or multiple female authors. Moreover, we found that 15 articles had only female authors. Thus to analyze the collaboration of both male and female authors, we discarded those studies and finalized 384 articles for our further investigation.

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

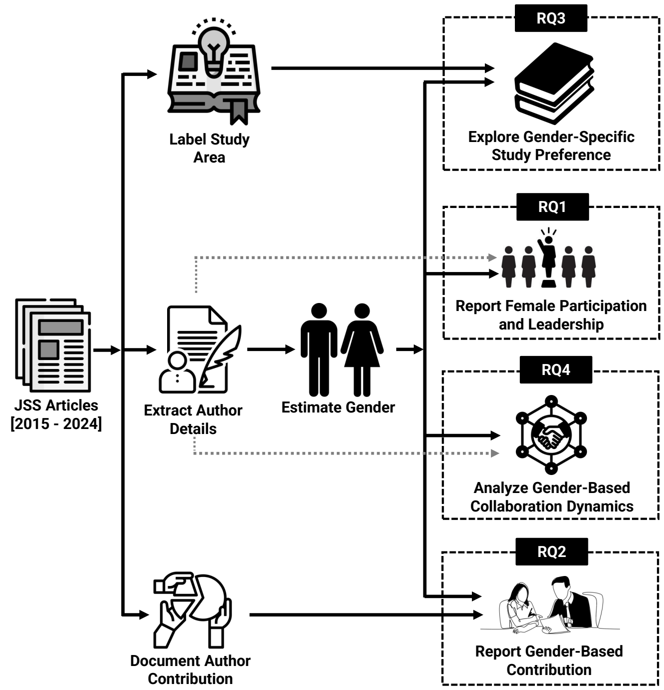

Fig. 1: Study methodology

TABLE I: Statistics of the collected articles

Year	# of articles with contribution section	# of articles without the contribution section
2015	0	181
2016	0	228
2017	0	207
2018	0	207
2019	0	174
2020	96	86
2021	123	36
2022	116	66
2023	197	39
2024	227	17

B. Author Information Record

We recorded all the author's names and affiliations for each of the publications. Then, we used GPT-4[2] and the genderize.io tool[3] to predict the authors' genders. Both of the tools have been widely used in the literature [30], [31]. First, we randomly selected 100 authors and checked the gender prediction using both tools. Then, we manually evaluated the authors' genders by reviewing the biographies provided at the end of each paper. We found that Genderize.io was unable to accurately determine the correct gender in some cases. For example, it was either assigning the wrong gender or returning 'unknown'. Finally, we used the GPT-4 model to identify the genders of the remaining authors for all the articles.

[2]https://openai.com/index/hello-gpt-4o/
[3]https://genderize.io/

TABLE II
Dataset collection filtration

# of Articles (2015-2024)	Contribution-based filtration	Articles with one/multiple female authors	# of Female-only articles	Finally selected articles that have both male & female contribution
2000	763	399	15	384

TABLE III
Contribution details

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.

C. Author Contribution Record

Two authors manually checked the *CRedit* section for each study and recorded each author's contribution role. For each role, they assigned a value of 1 if an author contributed and 0 if they did not. This procedure was repeated for all 14 contribution roles.

D. Investigating the participation of female authors (RQ_1)

We analyzed the female authors' participation and leadership roles across all studies. We calculated the ratio of male to female authors, both in general author contributions and specifically in lead positions.

E. Analyzing commitment and contribution of the female authors (RQ_2)

F. Emphasizing areas of software systems with female leadership and contribution (RQ_3)

We use 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 first compile a set of 384 research articles that feature at least one female author. The first two authors collaboratively label each selected article based on its title, abstract, and keywords. They use open codes that reflect the study's focus. For instance, Zhu et al. [32] examined the relationship between observability metrics and mutation scores. Their study included labels such as "testing techniques" and "code quality and maintenance." In cases where disagreements arose during the coding process, we discussed the issues until a consensus was reached.

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. [33]. 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, 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 codebook 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.

G. Exploring the collaboration dynamics of the female authors in software system research (RQ_4)

We extracted information on each author's country and institution based on their affiliations. We aimed to determine whether the study involved local, national, or international collaboration. For example, when all the authors are from the same institution, we call it local collaboration. At first, we analyzed collaboration dynamics across all articles. Then we compared these patterns specifically in studies led or supervised by female authors and conducted a similar analysis for male-led and male-supervised studies.

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

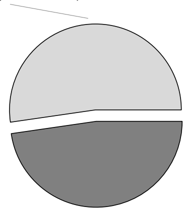

Fig. 2: Ratio of publications consisting one/multiple female authors vs no female authors

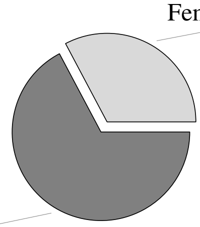

Fig. 3: Ratio of total female and male authors in female-contributed articles

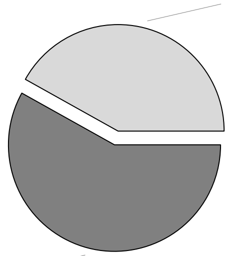

Fig. 4: Ratio of female-led and male-led studies

In this section, we analyze the participation and leadership skills of women in software system research. As shown in Fig. 2, out of the 763 total studies, 52.29% (399 out of 763) articles have one or multiple female authors, and the rest of the studies, i.e., 47.71% (364 out of 763) have no female authors at all Cynthia ►should we consider 399 here or 384?◄ . 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. Fig. 3 shows the pie chart distribution of the total male and female authors in our selected paper. The ratio illustrates the low presence of females in software system research. Out of 1,771 total authors, only 580 authors (i.e., 32.74%) are female, and 1,191 authors (i.e., 67.25%) are male. Such statistics encouraged us to further analyze the ratio of female-led and male-led studies. Fig. 4 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 indicates that female leadership is prominent and gaining momentum.

Summary of RQ_1: A significant portion of the studies does not have any female authors, and the ratio of female authors (32.74%) in those studies is notably low. However, female participation in the leading role (41.92%) indicates that while a gap exists, their participation is not far behind in the research leadership.

V. Female Leadership and Contribution Across Key Areas (RQ_3)

VI. Collaboration dynamics of women in Software System Research (RQ_4)

In this section, we aim to explore the collaboration dynamics of female authors in software systems research at local, national, and international levels. Fig. 5 highlights the collaboration pattern for all of the 384 articles. We find that 24.23% (93 out of 384 articles) of the collaborations are local, 45.57% (175 out of 384 articles) are national, and 54.43% (209 articles) involve international collaboration. To gain deeper insights into how female participation can influence these collaboration patterns, we further investigated the distribution of female-led versus male-led studies and female-supervised versus male-supervised studies.

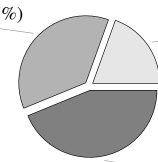

Fig. 5: Collaboration dynamics of all the studies

Fig. 6 and Fig. 7 illustrate the collaboration dynamics for the female-led and male-led studies. For female-led studies (Fig. 6), the distribution of collaboration types highlights a relatively balanced pattern. A slightly lower ratio for local collaboration, i.e., 37.63% (35 articles), and close to similar collaboration at national and international levels, 42.86% (75 articles) and 41.15% (86 articles), respectively. This distribution suggests that female-led research teams tend to engage in a balanced mix of collaborations across different levels, with a slight preference towards national collaboration. In contrast, male-led studies (Fig. 7) highlight a higher dependence on local collaboration, i.e., 62.37% (58 articles) in total. This

TABLE IV: Gender-Based Leadership and Supervision of Articles in Key Areas of Software Systems Research

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

ratio significantly surpasses the national and international collaboration, 57.14% (100 articles) and 58.85% (123 articles), respectively. 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 spread their collaborations more evenly across national and international levels.

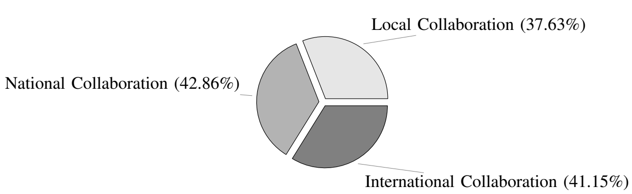

Fig. 6: Collaboration dynamics of female-led studies

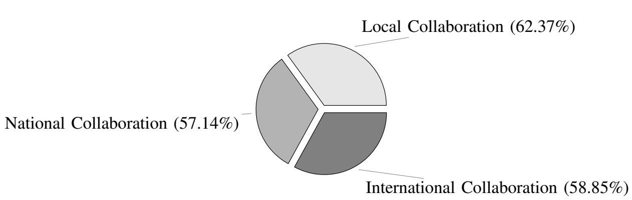

Fig. 7: Collaboration dynamics of male-led studies

Fig. 8 and Fig. 9 illustrate the collaboration dynamics for the female-supervised and male-supervised studies. While performing our analysis, we found that among 384 articles, 163 articles have both male and female authors in the supervision role, and 221 articles have either female or male supervision, 45 and 176 respectively. Thus, to focus on how collaboration dynamics change when only one gender is supervising the research, we excluded the 163 articles that involved both male and female supervisors. For female-supervised studies (Fig. 8), international collaboration stands out, accounting for 53.33% (24 articles). This indicates that female-supervised research teams often extend their work beyond national boundaries. A lower percentage of local collaboration, i.e., 33.33% (15 articles), compared to national collaboration, i.e., 46.67% (21 articles), suggests that female-supervised teams prefer to collaborate on a global scale rather than local networks. In comparison, the male-supervised studies (Fig. 9) show a significantly lower percentage of local collaboration, which makes up only 25.00% (44 articles) of the total. Whereas the national and international collaborations are relatively balanced, with 46.30% (87 articles) at the national level and 50.57% (89 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.

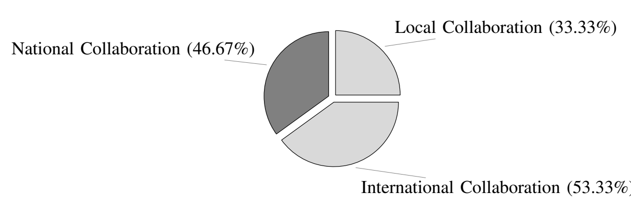

Fig. 8: Collaboration dynamics of female-supervised studies

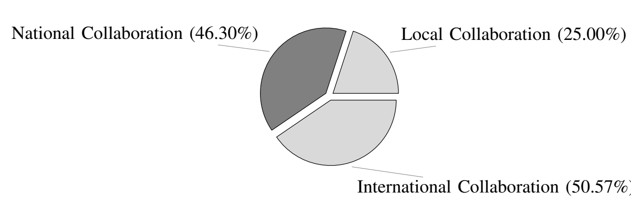

Fig. 9: Collaboration dynamics of male-supervised studies

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 (37.63%) 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 (53.33%) compared to male-supervised studies (50.57%). Interestingly, the remarkably lower percentage of male-supervised local collaboration (25.00%) indicates that male-supervised studies focus more on national and international collaborations, while female-supervised studies maintain a more balanced approach.

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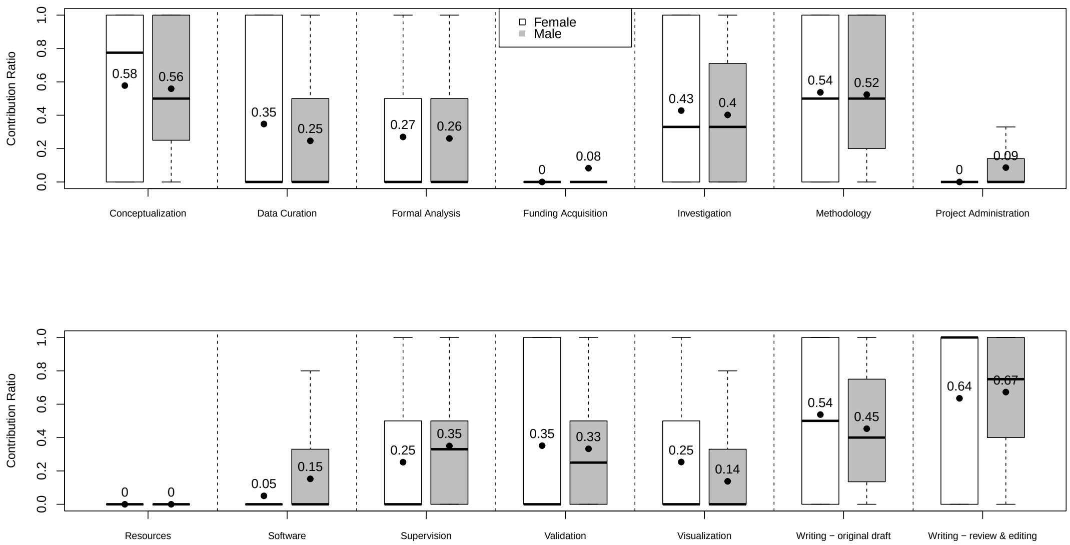


Fig. 10: Contribution Ratio

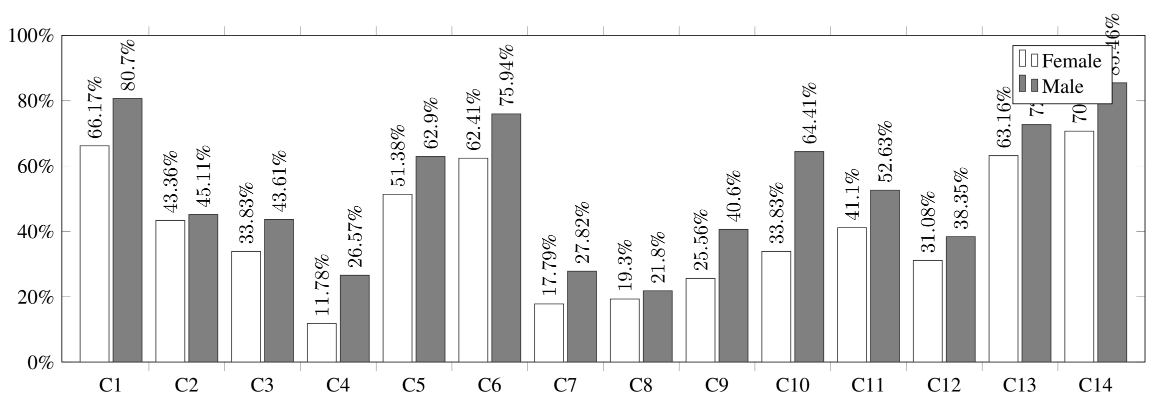
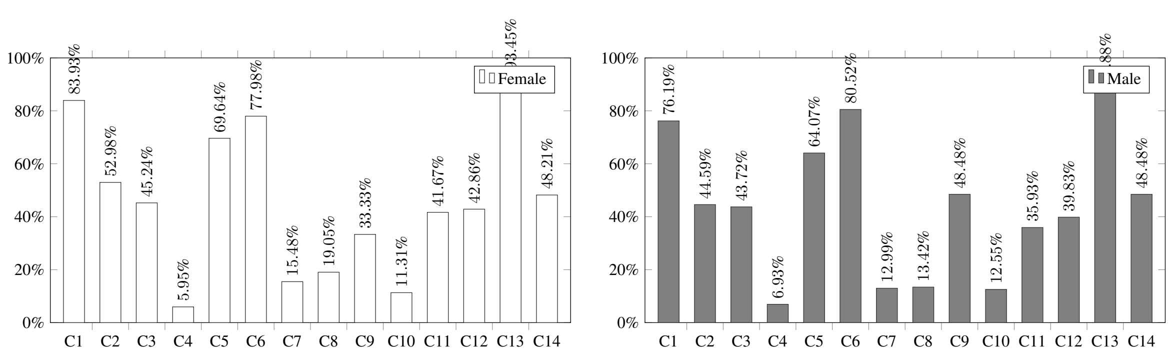
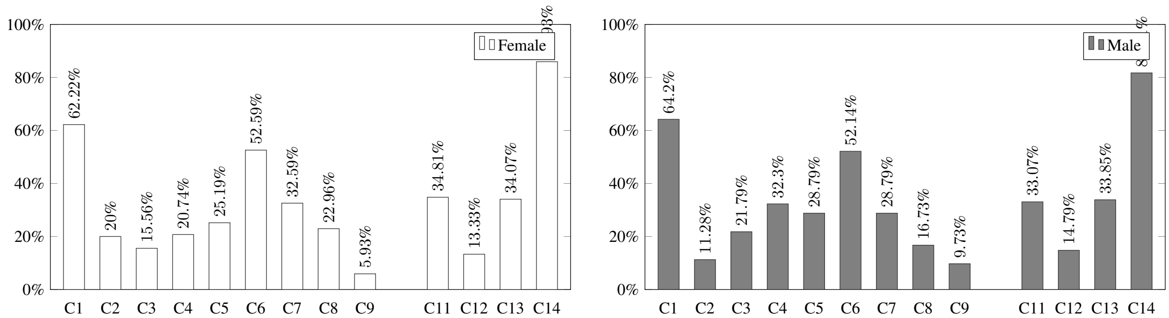


Fig. 11: Contribution ratio of all female and male authors



(a) Female Lead Ratio (b) Male Lead Ratio

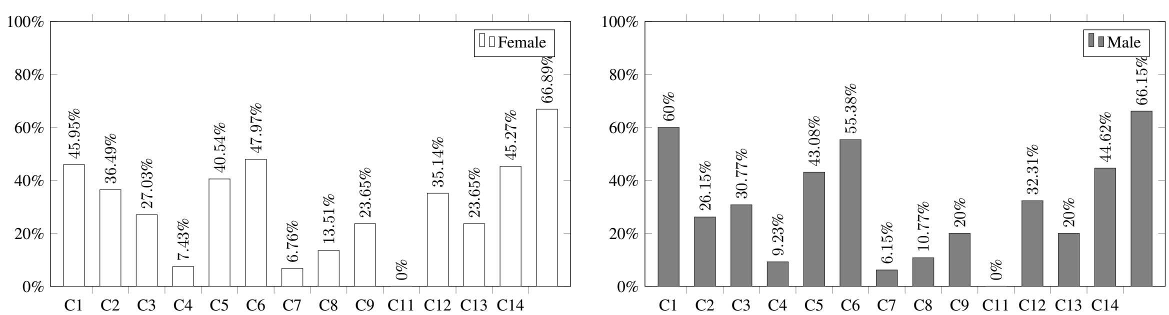
Fig. 12: Contribution ratio of female lead and male lead authors



(a) Female Supervisor Ratio

(b) Male Supervisor Ratio

Fig. 13: Contribution ratio of female supervisor and male supervisor authors (except *Supervision* contribution



(a) Female no-lead no-supervision Ratio

(b) Male no-lead no-supervision Ratio

Fig. 14: Contribution ratio of female no-lead no-supervision and male no-lead no-supervision authors

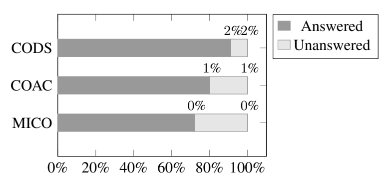


Fig. 15: Percentage of unanswered questions