

Investigating the Impact of Gender Diversity on Human Behavior in Proprietary Software Ecosystems

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Abstract. *Despite the growing discussion and concern about the topic, gender diversity in the Exact Sciences and Technology still requires attention and treatment. It has been observed by several authors that gender diversity is still not present in a significant way in development teams, despite its positive effect on them. With the growing demand for software that meet complex business needs, the concept of Software Ecosystems (SECO) has emerged. This research project aims to investigate how human behavior is affected by the presence or absence of gender diversity in a proprietary SECO and strategies to foster the gender diversity in this environment.*

Resumo. *Apesar da crescente discussão e preocupação com o tema, a diversidade de gênero nas Ciências Exatas e Tecnologia ainda requer atenção e tratativa. Foi observado por diversos autores que a diversidade de gênero ainda não está presente de forma significativa nas equipes de desenvolvimento, apesar do seu efeito positivo nos negócios. Com a crescente demanda de softwares que atendam as necessidades de negócio complexas surgiu o conceito de Ecosistemas de Software (ECOS). Este projeto de pesquisa visa investigar como o comportamento humano é afetado pela presença ou ausência da diversidade de gênero em ECOS proprietário e estratégias para promover a diversidade de gênero neste ambiente.*

1. Introduction

The topic of diversity and inclusion has been strongly discussed within organizations and academia. However, there is still a big space to improvement in the management of diversity in Brazilian organizations [Jabbour et al. 2011]. Although it is one of the largest global economies, Brazil still has social indicators of one of the most unequal societies in the world [Gonçalves 2016]. In a survey with more than 500 Brazilian companies conducted by the Ethos Institute for Social Responsibility (2016), it can be seen that women are still underrepresented in the industry, with a reduction in the number of women in higher positions in the hierarchy, such as 58.9% for interns and 11% for board of directions. Another example is that Women hold only 8.2% seats on boards of directors in SP500 companies in the United States in 2023 [Catalyst 2023].

The Information and Communication Technology sector has been growing at a fast pace in recent years. This sector traditionally demands a large number of professionals

in the areas of Science, Technology, Engineering and Mathematics (STEM) who, for the most part, are male professionals [Botella et al. 2019]. This sector has also been facing other challenges, such as the need of development of new, more modern and innovative systems that meet the ever-expanding business needs. From this need, software ecosystems (SECO) emerge as a solution to deal with these scenarios [Barbosa et al. 2013].

Through qualitative research, Ely and Thomas (2001) observed that the presence of diversity in an organizational group improves the effectiveness of the group in achieving its objectives. In its various forms of manifestation, diversity is increasingly present in the various sectors of industry [Wentling and Palma-Rivas 2000], leading the academia to study this topic and better understand the way and effects of diversity on the society in which it operates.

In software development, diversity has become a concern and also a frequent object of study, especially gender diversity, since it is still not being properly considered in team formation [Vasilescu et al. 2015]. Previous studies identified that gender diversity in the Board of Directors of companies has a positive impact on their market value and greater profitability [Campbell and Vera 2008, Arıoğlu 2020]. In SECO, where actors and their relationships are key roles, investigating and understanding the particularities of gender diversity are also important for the environment. Manikas and Hansen (2013) said that diversity is an important ingredient of the success of an ecosystem, because the differentiation of actors would allow niche creation. Despite not having many studies on the subject of technical, organizational, business, and social variability in harmonic symbiosis settings could bring more stability and possibly contribute to a healthier ecosystem.

2. Background

According to Jansen et al. (2009), a SECO consists of a set of actors that functions as a unit that interacts with a shared market of software and services, along with the relationships between these entities. Such relationships are usually supported by a common technological platform and carried out by exchanging information, resources and artifacts. These ecosystems require the integration of mechanisms and tools to provide the exchange of information, resources and artifacts, as well as ensure the communication and interaction of developers and users [Bosch 2011]. A Proprietary SECO (PSECO) is an ecosystem based on proprietary contributions. Ecosystems of this type are typically protected by intellectual property management processes and the value is related to monetary compensation, where new actors have to be certified to be allowed to participate in the ecosystem. This type of SECO can also be defined as a closed environment in which several platforms relate to each other, such as SAP [Manikas and Hansen 2013].

As a network of actors interacting with each other, the relationships can affect a SECO community and incur in social debt (*“not quite right development communities”* [Tamburri et al. 2013]). Community smells are one source of social debt and this term was formulated and refers to symptoms of the presence of social problems in a community [Palomba et al. 2017]. According to Tamburri et al. (2021), community smells are *“sub-optimal patterns through the organizational and social structure in a software development community that are precursors to unpleasant socio-technical events”*. Even if they are not an immediate problem, they can affect software in the long term [Almarimi et al. 2021].

In two surveys, one from 2010 and the other from 2022, it was possible to observe that software developers are predominantly male, showing that scenario has been maintained over the years. In the 2010 survey, it was estimated that women represented approximately 25-30% of employees in the IT industry [Hill et al. 2010]. In turn, the recent survey conducted by Stack Overflow¹ with more than 70,000 developers reports that about 92% of developers are men. In open source software (OSS), such scenario is repeated. According by Canedo et al. (2020), only 2.3% of core developers are women. Several authors observed that gender diversity in development teams increases productivity [Vasilescu et al. 2015, Foundjem et al. 2021]. However, despite the positive effect identified, most teams are still composed solely of male professionals, with a large gender gap to be filled.

Considering that diversity can be observed in any environment where different aspects stand out than those considered a normal pattern with a given statistical parameter [Martinez 2008]. According to Vasilescu et al. (2015) 75% of the evaluated projects did not have any gender diversity and only 1% of these projects that did not have diversity were from female-only teams.

Some related studies were important for the creation of this research project and are being considered in the construction and analysis of the results, such as: (i) the SMS by Trinkenreich et al. (2022) on the participation of women in OSS communities; (ii) the SLR study by Canedo et al. (2019), which aimed to identify factors to help increase women's interest in contributing to OSS communities; (iii) the study by Trinkenreich et al. (2022), in which an exploratory study was carried out in a software organization and it was identified that barriers for women in the IT industry; and (iv) the study by Canedo et al. (2021), in which a field study was carried out with female developers identifying the problems faced by women in male-dominated organizations.

3. Problem Characterization

With the lack of women in development teams, a PSECO also is impact by the lack of gender diversity in the teams. As a result, gender barriers prove to be more present and difficult to overcome. Furthermore, Manikas and Hansen (2013) observed in the literature that the papers studying open SECO are mostly concerned with problems of a technical or social nature. On the other hand, the papers studying PSECO include business and strategic problems, but not so much technical and social issues, so, there is a need to discuss more about social problems in PSECO.

This research aims to investigate and answer the main research question (RQ): **How does gender diversity affect human behavior in a proprietary software ecosystem?** As a way to answer the main research question, the following sub-questions were defined: **SQ1** - What are the effects on stakeholder relationships due to the identified barriers? **SQ2** - How is human behavior affected by the different types of gender in their relationships in the PSECO? and **SQ3** - Is there an human behavior pattern related with gender diversity in PSECO?

The main objective of this work is to contribute to understanding how human behavior may be affect by gender diversity in PSECO. Thus, an action framework will

¹<https://survey.stackoverflow.co/2022/>

be refined to foster the participation of women in PSECO. We will build a conceptual model on human behavior influenced by gender diversity in PSECO and a tool will be developed to instantiate the conceptual model and framework. After formulating RQ and main objective, some specific objectives were defined: 1. Refine barriers faced by women in PSECO and strategies to deal with the barriers; 2. Map how relationships between actors are affected in a PSECO; 3. Refine an action framework to organize a body of knowledge and to foster gender diversity in PSECO; 4. Investigate how the literature deals with gender diversity and community smells; 5. Identify how human behavior is affected by the different types of gender in a PSECO; 6. Identify a possible human behavior pattern related with gender diversity in PSECO; and 7. Create a conceptual model on human behavior influenced by gender diversity in PSECO.

4. Solution Proposal

As a result of the research, it is intended to achieve the following intermediate results: i) refining a body of knowledge on barriers and strategies to deal with gender diversity in PSECO; ii) defining a body of knowledge of human behaviour in the presence or absence of gender diversity in PSECO; and iii) identifying and implementing a tool to foster gender diversity in a PSECO. The tool will instantiate a refined action framework with barriers and strategies for dealing with gender diversity and a conceptual model on human behavior influenced by the absence or presence of gender diversity in PSECO. We aim to increase the body of knowledge on the topic and foster gender diversity in PSECO.

5. Research Method

This project combines different research methods, consisting of twelve steps and three phases: conception, implementation, and evaluation, as shown in Figure 1. The conception phase is the initial phase of this research project and involves the intellectual process of developing a research idea into a research design. The implementation phase involves applying research results into practice. Finally, the evaluation phase represents the visions and perspectives of practitioners and is focused on evaluating the built artifacts. Since the first 4 steps were carried out in the master's research, a refinement is being made. The other steps will be carried out in the doctoral project.

Activities performed in the master's research: **(1) Systematic mapping study (SMS) on diversity in SECO:** a SMS was carried out with the aim of identifying how diversity manifests itself in the context of SECO to identify how the topic has been discussed in the literature, the main approaches used to deal with diversity, and the effects observed when diversity is considered in a SECO. The study was published in the main track of the XVIII Brazilian Symposium on Information Systems (SBSI 2022) [Outão and Santos 2022]; **(2) Multivocal literature review (MLR) of gender diversity in SECO:** a MLR was performed, in which a SMS was carried out with the addition of gray literature. Its objective is to identify the main gender barriers mapped in software development teams and strategies to deal with these barriers. In the doctorate research, an update of the MLR was carried out to include studies published until August 2023, since there has been an increase in publications on the subject recently; **(3) Field study with women from PSECO:** in order to investigate more deeply the gender barriers faced by women who are part of development teams in a PSECO, a qualitative, exploratory and inductive field study was carried out, through structured interviews; and **(4) Actionable**

framework on gender diversity in PSECO (PSECO-GDI): this step aimed to build an action framework with suggestion of strategies to foster gender diversity in PSECO, through the list of barriers and strategies. This artifact was built based on the studies explained in the previous steps. The doctoral research activities are described as follows:

1. **Participative case study to evaluate and refine the framework:** in this step, an evaluation of the action framework will be carried out through a participative case study, where a manager of a PSECO development team will try to use the framework to eliminate one or more gender barriers identified in their team. Feedback on the use of the framework will be collected through meetings and adjustments will be made to the framework, if necessary.
2. **Systematic mapping study on community smells and diversity:** in this step, an SMS will be carried out to investigate the relationship between community smells and gender diversity described in the academic literature. The objective is to identify if there is a relationship between gender diversity and community smells and how it affect software development teams;
3. **Survey to understanding human behavior in the different genders in a PSECO:** in this step, a survey will be carried out to map responses that software developers may have (human behavior) when certain situations occur within a PSECO, considering the different genders existing in the PSECO. We will use as a basis the literature explored and field study performed in the master's research and refined in the doctorate research. This method was selected because we want to obtain answers to questions that express opinions, customs or characteristics of a specific target audience;
4. **Field Study to identify pattern of human behavior related to diversity in PSECO:** a field study will be carried out based on the answers from the survey as a basis to identify possible pattern of human behavior or community smells related to gender diversity, where developers of different genders in a PSECO will be interviewed;
5. **Conceptual model on human behavior influenced by gender diversity in PSECO:** in this step, a conceptual model will be built to map how human behavior is affected by gender diversity in a PSECO, considering the different existing power relationships;
6. **Tool to instantiate the conceptual model and framework (PSECO-HB-GDI²):** a tool will be created to instantiate the updated framework and the conceptual model created in this research project in order to disseminate its use and help the industry in the apply the research results from academia;
7. **Focus group for PSECO-HB-GDI evaluation:** this step aims to assess the use and suitability of the PSECO-HB-GDI approach for human behavior influenced by gender diversity in the PSECO based on the opinions of experts in PSECO;
8. **Participative case study in a PSECO:** this step aims to evaluate the PSECO-HB-GDI tool, using an approach of observe human behavior influenced by gender diversity in the PSECO. The approach will be evaluated in a large organization characterized as PSECO; and
9. **PSECO-HB-GDI refinement:** based on the results of the previous steps, we will be execute a refinement step to act on the adjustments identified.

²Proprietary Software Ecosystem - Human Behavior - Gender Diversity and Inclusion

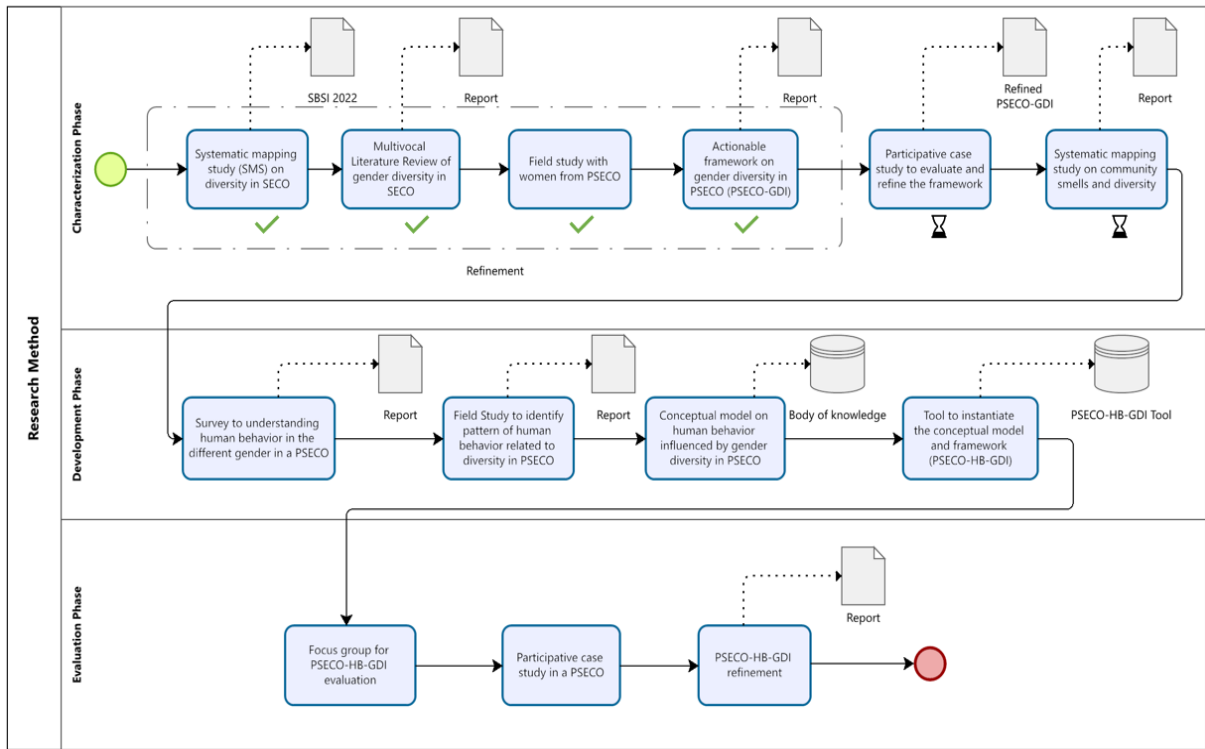


Figure 1. Research Method

6. Performed Activities

As previously mentioned, the first 4 activities of the research method were carried out in the master's project, executed during the years 2021-2023. However, a refinement of the steps taken and the results obtained is being performed. A MLR update was performed between April and August 2023 and the findings was reported.

7. Final Remarks

This research project has the main expected contributions: (i) a refined action framework to foster gender diversity in PSECO with the gender barriers and strategies to deal with the barriers; (ii) a map of the human behavior influenced by the different types of power relationships in a PSECO; (iii) a conceptual model for mapping human behavior influenced by the absence or presence of gender diversity; and (iv) a tool to instantiate the framework and conceptual model to disseminate the knowledge obtained.

For the academy, we seek to further investigate the topic of gender diversity in PSECO, increase the body of knowledge on the subject and create artifacts to facilitate the dissemination and continuation of studies such as SMS, MLR, and conceptual model. For the industry, we seek to consolidate the knowledge acquired into easy-to-use artifacts, such as the PSECO-GDI framework and the PSECO-HB-GDI tool, in order to help PSECO decision makers to foster gender diversity in their teams internally and in its relations with other PSECO actors. The main benefits are: (i) help keystone managers to map potential existing gender barriers in their teams; (ii) identify strategies to deal with these barriers (action framework); (iii) map of human behavior patterns influenced by the absence or presence of gender diversity to help the identification these behaviors

in the development teams; and (iv) be able to take the necessary actions to foster gender diversity in PSECO (conceptual model).

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References

- Almarimi, N., Ouni, A., Chouchen, M., and Mkaouer, M. W. (2021). csdetector: an open source tool for community smells detection. In *Proceedings of the 29th ACM Joint Meeting on European Software Engineering Conference and Symposium on the Foundations of Software Engineering*, New York, NY, USA. ACM.
- Arioğlu, E. (2020). Female board members: the effect of director affiliation. *Gender in Management*, 35:225–254.
- Barbosa, O., Santos, R., Alves, C., Werner, C., and Jansen, S. (2013). *Chapter 4: A systematic mapping study on software ecosystems from a three-dimensional perspective*. Edward Elgar Publishing, Cheltenham, United Kingdom.
- Bosch, J. (2011). Software ecosystems – implications for strategy, business model and architecture. *2011 15th International Software Product Line Conference*, pages 351–351.
- Botella, C., Rueda, S., López-Iñesta, E., and Marzal, P. (2019). Gender diversity in stem disciplines: A multiple factor problem. *Entropy*, 21(1):30.
- Campbell, K. and Vera, A. (2008). Gender diversity in the boardroom and firm financial performance. *Journal of Business Ethics*, 83:435–451.
- Canedo, E., Bonifácio, R., Okimoto, M., Serebrenik, A., Pinto, G., and Monteiro, E. (2020). Work practices and perceptions from women core developers in oss communities. In *Proceedings of the 14th ACM / IEEE International Symposium on Empirical Software Engineering and Measurement (ESEM)*, ESEM '20, New York, NY, USA. Association for Computing Machinery.
- Canedo, E., Mendes, F., Cerqueira, A., Okimoto, M., Pinto, G., and Bonifacio, R. (2021). Breaking one barrier at a time: How women developers cope in a men-dominated industry. In *Proceedings of the XXXV Brazilian Symposium on Software Engineering, SBES'21*, page 378–387, New York, NY, USA. Association for Computing Machinery.
- Canedo, E., Tives, H., Bogo, M., Fagundes, F., and Cerqueira, J. (2019). Barriers faced by women in software development projects. *Information*, 10:309.
- Catalyst (2023). *Women CEOs of the S&P 500 (List)*. Catalyst.
- Ely, R. and Thomas, D. (2001). Cultural Diversity at Work: The Effects of Diversity Perspectives on Work Group Processes and Outcomes. *Administrative Science Quarterly*, 46(2):229–273.
- Foundjem, A., Eghan, E., and Adams, B. (2021). Onboarding vs. Diversity, Productivity and Quality — Empirical Study of the OpenStack Ecosystem. In *2021 IEEE/ACM 43rd International Conference on Software Engineering (ICSE)*, pages 1033–1045.

- Gonçalves, B. (2016). *Perfil social, racial e de gênero das 500 maiores empresas do Brasil e suas ações afirmativas*. Banco Interamericano de Desenvolvimento.
- Hill, C., Corbett, C., and Rose, A. (2010). Why so few? women in science, technology, engineering, and mathematics. *American Association of University Women*.
- Jabbour, C. J. C., Gordon, F. S., Oliveira, J. H. C. d., Martinez, J. C., and Battistelle, R. A. G. (2011). Diversity management: challenges, benefits, and the role of human resource management in Brazilian organizations. *Equality, Diversity and Inclusion: An International Journal*, 30(1):58–74.
- Jansen, S., Finkelstein, A., and Brinkkemper, S. (2009). A sense of community: A research agenda for software ecosystems. *2009 31st International Conference on Software Engineering - Companion Volume*, pages 187–190.
- Manikas, K. and Hansen, K. M. (2013). Software ecosystems – A systematic literature review. *Journal of Systems and Software*, 86(5).
- Martinez, V. (2008). *Gestão da diversidade e pessoas com deficiência: percepção dos gestores e empregados sobre os impactos da lei de cotas*. Mestrado em Administração, Universidade de São Paulo, São Paulo.
- Outão, J. and Santos, R. (2022). How does diversity manifest itself in software ecosystems? In *XVIII Simpósio Brasileiro de Sistemas de Informação — SBSI 2022*, Curitiba, Brazil. Association for Computing Machinery.
- Palomba, F., Serebrenik, A., and Zaidman, A. (2017). Social debt analytics for improving the management of software evolution tasks. *CEUR Workshop Proceedings*, pages 18–21. CEUR-WS.org.
- Tamburri, D. A., Kruchten, P., Lago, P., and van Vliet, H. (2013). What is social debt in software engineering? In *2013 6th International Workshop on Cooperative and Human Aspects of Software Engineering (CHASE)*, pages 93–96.
- Tamburri, D. A., Palomba, F., and Kazman, R. (2021). Exploring community smells in open-source: An automated approach. *IEEE Transactions on Software Engineering*, 47(3):630–652.
- Trinkenreich, B., Britto, R., Gerosa, M., and Steinmacher, I. (2022a). An empirical investigation on the challenges faced by women in the software industry: A case study. In *2022 IEEE/ACM 44th International Conference on Software Engineering: Software Engineering in Society (ICSE-SEIS)*, pages 24–35.
- Trinkenreich, B., Wiese, I., Sarma, A., Gerosa, M., and Steinmacher, I. (2022b). Women’s participation in open source software: A survey of the literature. *ACM Trans. Softw. Eng. Methodol.*, 31(4).
- Vasilescu, B., Serebrenik, A., and Filkov, V. (2015). A Data Set for Social Diversity Studies of GitHub Teams. In *2015 IEEE/ACM 12th Working Conference on Mining Software Repositories*, pages 514–517, Florence, Italy. IEEE.
- Wentling, R. and Palma-Rivas, N. (2000). Current status of diversity initiatives in selected multinational corporations. *Human Resource Development Quarterly*, 11(1):35–60.