Women in the Fab Lab ecosystem (2008-2021). From Fab Academy to the Fab Lab Research Conferences

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Abstract

Fab Lab ecosystem are conducive to the integration of women with an interest in STEM areas, enhancing opportunities in different areas of engineering and related disciplines. This integration is not only from practical research, but also in scientific production. To identify the presence of women in the Fab Lab ecosystem, a quantitative analysis was carried out, identifying two contexts: Fab Academy between 2008 and 2021, and Fab Lab Research Papers between 2012 and 2019. The results reveal aspects that benefit the presence of women, supported by the Fab Labs project-based learning model, which does not distinguish between genders and promotes collaboration, experimentation and knowledge exchange, among others. Similarly, new ways to become aware of technology are identified, which prioritizes interdisciplinary, through regional and global activities. Based on this analysis, the Fab Labs ecosystem is expected to further promote the presence of women as key actors, promoting their vision, analysis and dedication; and promoting their participation in instances of "doing" from practical experimentation and writing what is "done" from written production.

Keywords

Women, gender, Fab Lab, Fab Academy, Fab Lab Research

1 Introduction

In the history of research in engineering education, unintentional gender discrimination is still present for different reasons (Williams, 2002; Faulkner and Lie, 2007), decreasing women choosing STEM-related careers in recent decades (González-González, 2018) and the question persists: "Why women leave engineering?" (Fouad and Singh, 2012; Hunt, 2016; Singh et al., 2018). Without differentiating and pointing towards some type of methodology, Du (2006) affirmed that the engineering students associated the discipline with attributes such as problem-solving, analysis, logic, structure, focus, rationality, nerdiness, and masculinity, with themes that privilege men, imposing themselves as a barrier for women. However, this difference is not the result of inequalities in aptitude or fundamental skills such as mathematics; but rather, they are increasingly the attitude and psychological variables (Meiksins et al., 2019). Vitores and Gil-Juárez (2015) found in the literature review four psychological aspects that explain

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why girls avoid computer-related subjects specifically, and science, engineering, technology, and mathematics generally. (STEM): a) does not promote interpersonal ability b) are specialties dominated by men who work with machines c) don't perceive technology as a profession and d) their subjects are unappealing and/or boring. However, our research on the participation of women in the Fab Labs ecosystem reveals that the learning system produces new ways of becoming aware of technology, despite the difficulties that arise in the STEM education system.

2 Background. The Fab Academy and the Fab Lab Research Papers

When we read about makers or Fabrication Laboratories (Fab Labs), we associate that learning with digital media is a catalyst for creative processes. However, the nature of its origin goes beyond technology. The founders of the Maker or Fab Labs movements evidenced that the thinking of Montessori (Dougherty, 2016:182), Piaget, and Papert (Gershenfeld et al., 2017:29) directly or indirectly affected the learning methodology. Therefore, the Fab Lab ecosystem promotes and fosters interest in science and engineering (Blikstein, 2016) in spaces where gender plays no significant role (Carstensen, 2013).

The main reason for it is the philosophy of "to make (almost) anything" promoting collaboration, empowerment, and the democratization of technology (Gershenfeld, 2005, 2017) and recently sustainability (Kohtala, 2016). Fab Lab ecosystem prioritizes flexibility, interdisciplinary with different regional and global activities, which seems to attract the female gender as a whole. Therefore, we critically analyse the presence of women in the context of Fab Labs, to identify models and opportunities not only for our community but also for the STEM and engineering communities.

2.1 Fab Academy

This is the first context of our research. From here, the presence of women in workspaces will be analysed, with a characteristic that makes them unique and attractive to enhance creativity. Blikstein (2018), when referring to fabrication spaces, points out the convergence of five trends since the first decade of the 21st century: Hackerspaces, Makerspaces, Fab Labs, Commercial Ventures and TechShops. The Hackerspaces and Makerspaces represent the self-managed initiatives that advance from informal, unstructured learning but with media that promote a lot of activity, with magazines such as Makezine, Makerfaires and meetings inspired by exploring technology. On the other hand, the Fab Labs associated with the Fab foundation, consolidates a learning model through the Fab Academy. This is a hybrid-distributed model that uses labs implemented with digital fabrication technologies and synchronous and asynchronous online communication allowing the campus to go to the student.

The history of the Fab Academy begins in the pedagogy section of the Media Lab's Physics and Media group with the MAS.863 How To Make (Almost) Anything (HTMAA). Course directed by Neil Gershenfeld, Joe Jacobson, Scott Manalis, Joe Paradiso and Ted Selker. This course was organized with 12 topics divided into four groups: 1.CAD (design tools), 2.Fabrication (Laser and Waterjet Cutter, 3D Printing, 3D scanning), 3.Machining (traditional and numerical control) and 4.Electronics (Analog, PCB layout, microcontroller programming, sensors and communication). As of 2021, the program runs between January and June, concentrated in 20 units taught each week: 1.Principles and Practices, 2.Project Management, 3.Computer-Aided Design, 4.Computer-Controlled Cutting, 5.Electronics Production, 6.Computer-Controlled Machining, 7.Electronics Design, 8.Molding and Casting, 9.Composites, 10.Embedded Programming, 11.3D Scanning and Printing, 12.Input Devices, 13.Interface and Application Programming, 14.Mechanical Design, 15.Output Devices, 16.Networking and Communications, 17.Machine Design, 18.Applications and Implications, 19.Project Development and Invention, 20.Intellectual Property, and Income.

In Fall 1998, the MAS.863 began. In 2008 the first edition of the Fab Academy was held in this course with the participation of eight students (Fab Academy, 2017), and in 2009, the Fab Academy brand went global. On July 31, 2021 (https://www.fablabs.io/labs), 2030 Fab Labs was located in 127 countries. From that list, Fab Foundation classifies Fab Labs in four statuses: Active (1,136 Fab Labs), Planned (229), CORONA (32 linked to activities associated with COVID-19), and Closed (52).

Of all Fab labs, those who apply and meet the conditions to teach the Fab Academy program, become Fab Academy Nodes. In 2010, 12 Fab Academy Nodes were accredited (Fab Academy, 2020). In 2020, they reached 64 Fab Labs Nodes, and in 2021, the total of nodes was 76.[1] (The total number of Fab Academy graduates between 2009 and 2021 was 963.[2] However, in our study, we identified 1191 graduates.

In Fig. 1., we show the annual evolution of total graduates between 2009 and 2021, with a growth rate of 37.46%. Two graduates in 2009 and 70 in 2014; the growth rate was 103.62%. In 2015, there were more than 100 graduates, and in 2017, the Fab Academy reached the highest number of graduates with 185. As of that year, the number of graduates decreased by 2021, with 91 graduates. In this context of the practices, we ask ourselves about the evolution of women who graduated from the Fab Academy, the location, and the Nodes that had more female graduation to propose a preliminary approximation of quantitative information.

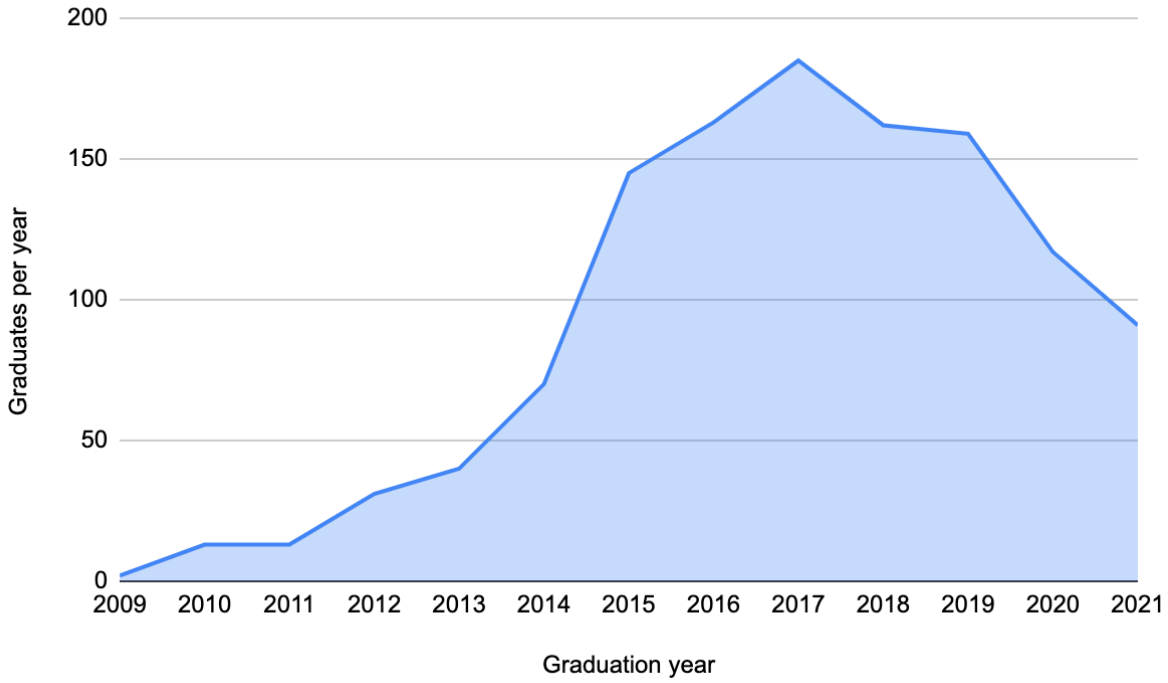

Figure 1: Annual evolution of Fab Academy graduates between 2009 and 2021. (Authors)

2.2 Fab Lab Research Papers

In the second context, we wonder if there is a relationship between practices and practice in a Fab Academy in terms of scientific production. Here, we consider that one of the most difficult situations in creative work in a Fab Lab is storing the details of the design process. The processes disappear while we eliminate the remains of a drawing, the parts of a prototype, until finally and with no other trace than images or documentation videos, our process becomes an object. We only have our memory to remember its evolution or some technology that we had used to visually document the process. However, neither photography nor video can preserve the design criteria, because they were not the instrument of the process. Despite this, writing the practices is a complex process that does not show growth similar to the appearance of Fab Labs in the world. In the exponential growth of Fab Labs, it is not usual to write about "doing" nor the theoretical reflection of practice. Not for lack of interest, but because the time for practical exploration exceeds the time for writing, focusing on improving our techniques (Herrera, 2019). The first Fab Lab was created outside the USA in 2002, but it was not until 2012 that the first call for papers appeared with the initiative of Peter Troxler (2018). Troxler (2018) evidenced the origin of the Fab Lab

[1] https://fabacademy.org/nodes/list2021.html

[2] https://fabacademy.org/students/alumni-list.html

Research Papers with an analysis of the areas of interest. In this history, were published 123 research papers in the Fab Lab Research (2012-2019). In 2020, the call for papers was not held due to the COVID-19 emergency. In addition, for the first time in 2021, the Woman Track appeared, but it was not included in this research because of the blind review process.

In Fig. 2, we show the annual number of papers, with only four (2012) and 38 (2014). From 2014 to 2019, their number has not exceeded 20 per year. In the analysis that we present, we identify the number of papers with female authors.

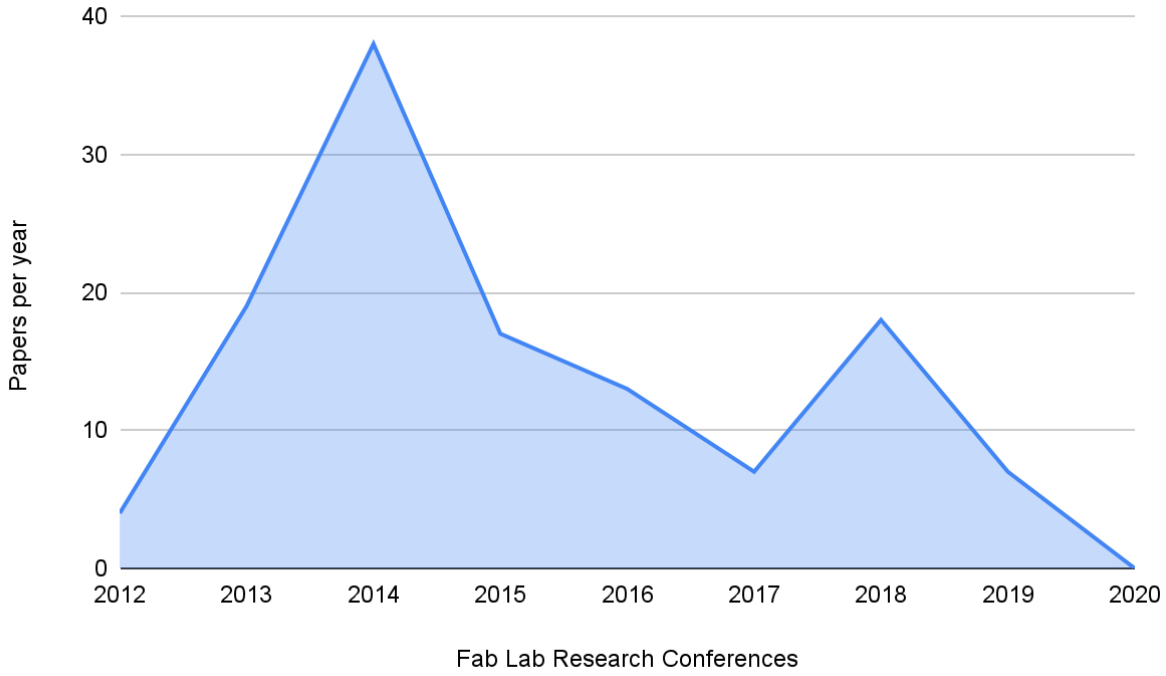

Figure 2: Annual evolution of papers in the Fab Lab Research Paper between 2012 and 2020. (Authors)

3 The Role of Women

The origin of the do-it-yourself (DIY) tradition dates back to a predominantly female environment, where working from home allows flexibility and empowerment (Winter, 1975; Callen, 1984). The DIY context advanced exponentially and has been strengthened with the more than 2000 Fab Labs registered in the world. Despite the high presence of the male gender in Fab Labs (Voigt & Unterfrauner, 2017; Marić, 2018), it seems that Fab Labs are male-dominated spaces.

Although the Fab Labs communities were created by men, we found that their management is often led by women. Some examples are Sherry Lassiter (Fab Foundation); Christina Rebel (Wikifactory); Anna Kaziunas (Dean of Fab Academy, 2016) or Anastasia Pistofidou and Cecilia Raspanti (Fabricademy). However, not only, promoting the management of the digital fabrication ecosystem, but also empowering women from girls to adults, as is the case of Nuria Robles (Poderosa, only for girls), Alejandra Díaz de León (Fab Lat Kids), Ilaria La Manna (EMOsilla) and Delia Barriga (FAB Women). The combination of administrative roles with STEM practice has created a culture of service and collaboration, along with interdisciplinary learning, becoming a sustainable practice over time.

4 Methodology

As we reviewed in the previous sections, we analysed the presence of women in the Fab Lab ecosystem, based on two groups: the Fab academy program and research published in the Fab Lab Research Paper.

We performed a quantitative analysis to identify the number of women participating in both groups. For the first, the list of all students to the Fab Academy from 2009 to 2021 was analysed. We identify the gender and the location of the Fab Academy Nodes with women graduated. Then, we processed the data establishing results for each year of the course. Based on this, we made various reflections on the evolution and growth in terms of female participation in the Fab Academy. The research originates from public information on the number of graduates of the program.[3] We gathered information from each graduate in order to complete the relevant data for this research. In the case of Fab Lab Research Papers, we analysed public information and repositories where the call for papers were published, as was the case of http://empty-ice-3260.herokuapp.com (for years 2012, 2014, 2016, 2017, 2018, 2019), EasyChair (for years 2016, 2018, 2019), and personal files and emails.

5 Case Study and Results

Three annual reports evidence the percentage of women that joined Fab Academy (Table 1). This little evidence reveals the need to research the presence of women in the Fab Lab ecosystem, and this defines the beginning of future research, to delve into the circumstances that would go beyond the statistics that we present.

Annual Report	Female	Male	Not to disclose
2017	25%	75%	0%
2018	25%	75%	0%
2019	24%	74%	2%

Table 10: Percentage of female applicants to the Fab Academy 2017-2019.

5.1 Presence of Women in the Fab Academy

As we reviewed in the previous section, the MAS.863 was the origin of the Fab Academy. In 1998, this course registered six women out of 16 students.[4] In 2005, Sherry Lassiter (then Program Manager, CBA MIT Media Lab) was one of six women who followed MAS.863 out of 14 students.[5] These antecedents of prominent women with no experience in digital fabrication were not accidental. Gershenfeld (2005) described the work of her star students: Kelly Dobson and the ScreamBody project, who was followed by other women with a vision of personalizing and appropriating technology, such as Meejin Yoon, Shelly Levy-Tzedek and Dalia William, an 11-year-old girl who along with other girls participated in classes at the South End Technology Centre (SETC, Boston). Girls at SETC found “that the things they make can be commercially as well as personally rewarding” (Gershenfeld, 2005).

In Fig. 3., we show the annual growth of women graduates from the Fab Academy. Of the total number of graduates between 2008 and 2021, we identify that the male population reached 862 graduates (72%) and the female population 329 graduates (28%). The records of the first Fab Academy in 2008,[6] indicate 13 students, of which 5 women completed the final project in the MAS.863 and only 8 students men at the Fab Academy with no female presence.

[3] https://fabacademy.org/students/alumni-list.html

[4] http://www.media.mit.edu/physics/pedagogy/fab/fab98/fall1998.html

[5] https://fab.cba.mit.edu/classes/863.05/people/

[6] https://fab.cba.mit.edu/classes/863.08/people/

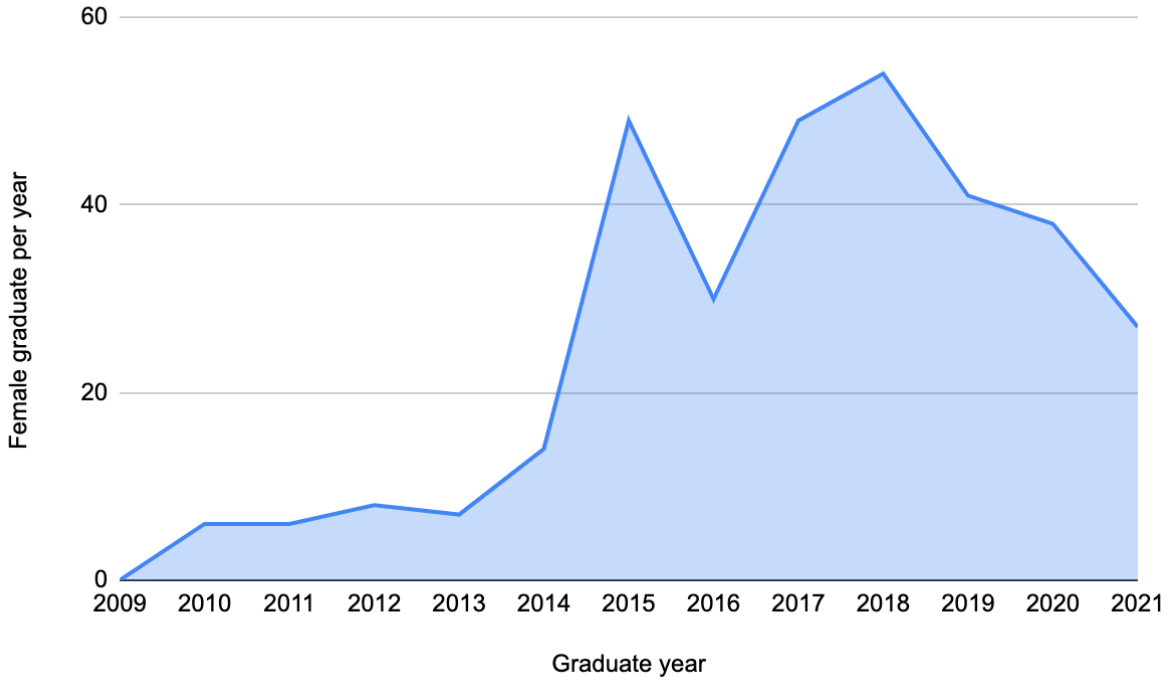

Figure 3: Annual growth of women graduates from the Fab Academy. (Authors)

The growth curve from 2010 to 2013 was very similar each year, with variations from six to eight female graduates). However, the percentages of the total number of graduates show a high presence of women, percentages close to fifty percent (in 2010 and 2011 it was 46%). In 2012, it reached 26%, with variations that reached the 2015 mark a presence of 34% over the total of graduates of that year. A very similar percentage that was repeated in 2018 (33%) and 2020 (32%), to reach 30% in 2021 (see details in Fig. 4).

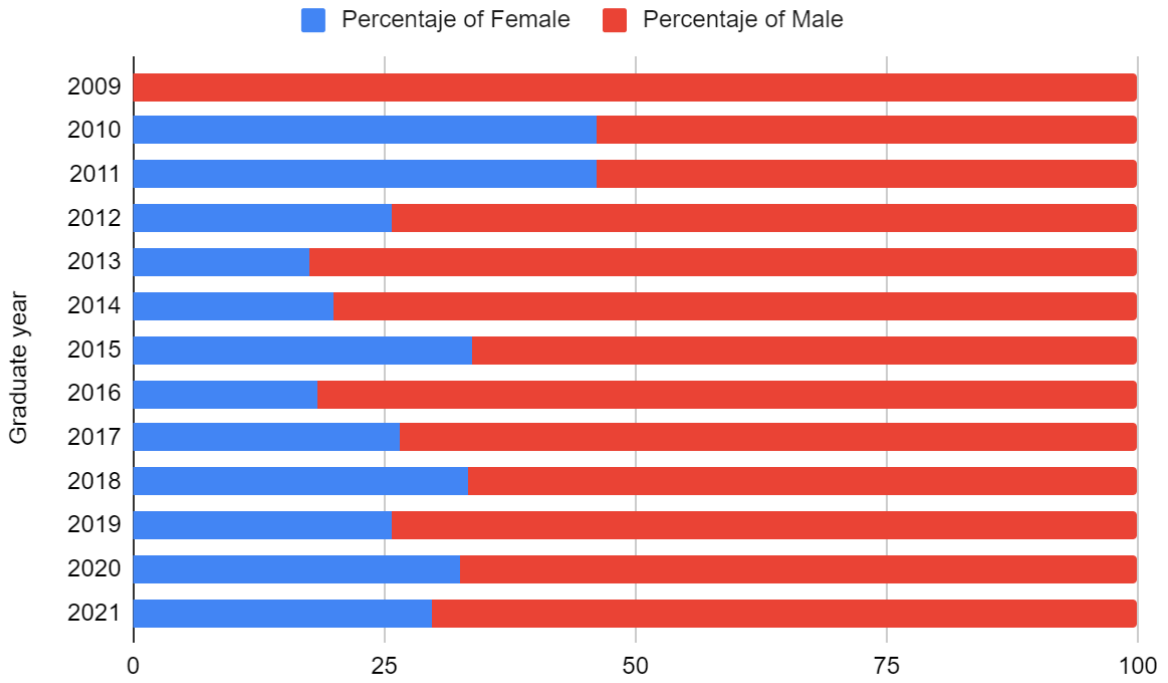

Figure 4: Annual percentage of presence of women with respect to the number of male graduates. (Authors)

Regarding the identification of the country of graduation, the women chose one of the 104 Fab Academy Nodes distributed in 43 countries to take the Fab Academy in the range of years of this research. Figure 5

shows the number of women graduates by country. Spain, one of the first countries to promote the Fab Academy, reached a total of 56 women graduates in 13 years, a number higher than the 41 women graduates from the United States of America (USA) where the program originated. These countries are followed by Fab Labs, with women graduated located in India (23), Italy (20), Netherlands (19), Finland (16), Peru (12), China (10) and Germany (10). The countries with the fewest female graduates are Russia (1), Uruguay (1), Kenya (1) and Pakistan (1). At this point, not all Fab Labs per country are considered to become Fab Academy Nodes, which is a requirement for the Fab Academy.

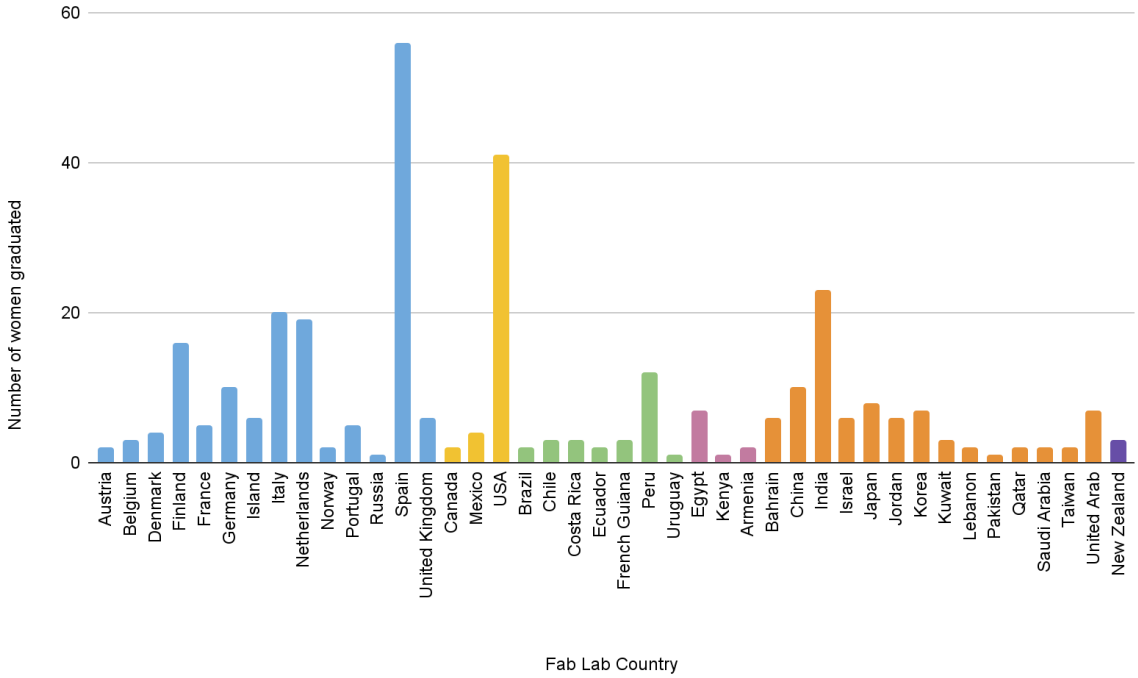

Figure 5: Mapping the Fab Academy Nodes with women graduated (2008-2021)

In our analysis by region and country (Fig. 5), we found that Europe and the United Kingdom have the highest number of women graduates, reaching 155 in 13 years, following Asia (87), North America (47), Central and South America (26), Africa (8) and Oceania (2).

The first six women graduated in 2010 studied at Fab Lab Barcelona (4) and AS220 Providence (2). In 2011, six Fab Labs graduated five women, and the Champaign-Urbana Community Fab Lab was the only one to graduate two women.

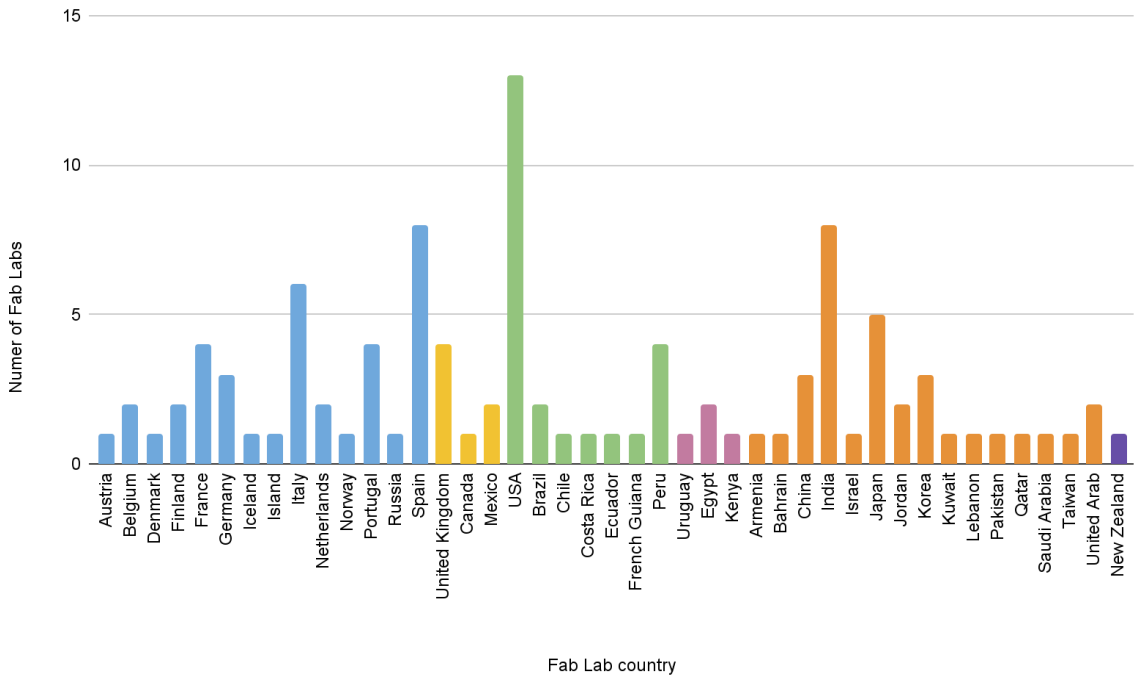

Figure 6: Number of Fab Academy Nodes by country with woman graduates (2008-2021) (Authors)

We show (Fig. 6.) three countries with the highest number of Fab Labs graduating women: USA, Spain and India. When analysing the number of Fab Academy Nodes by country, we found that the USA graduated 41 women distributed in 13 Fab Labs, with two Fab Labs exceeding 10 graduates, the Fab Lab AS220 - Providence with 11 graduated women and the Fab Lab Charlotte Latin with 10 graduated. Spain had the highest number of graduates (56) of all countries, with graduates distributed in seven Fab Academy Nodes. In Spain, the Fab Lab Barcelona was the facility that has graduated the most women in the history of the Fab Academy, with 42 women graduates. In India, 23 women graduates studied in nine Fab Labs, where the Fab Lab Vigyan Ashram graduated seven women.

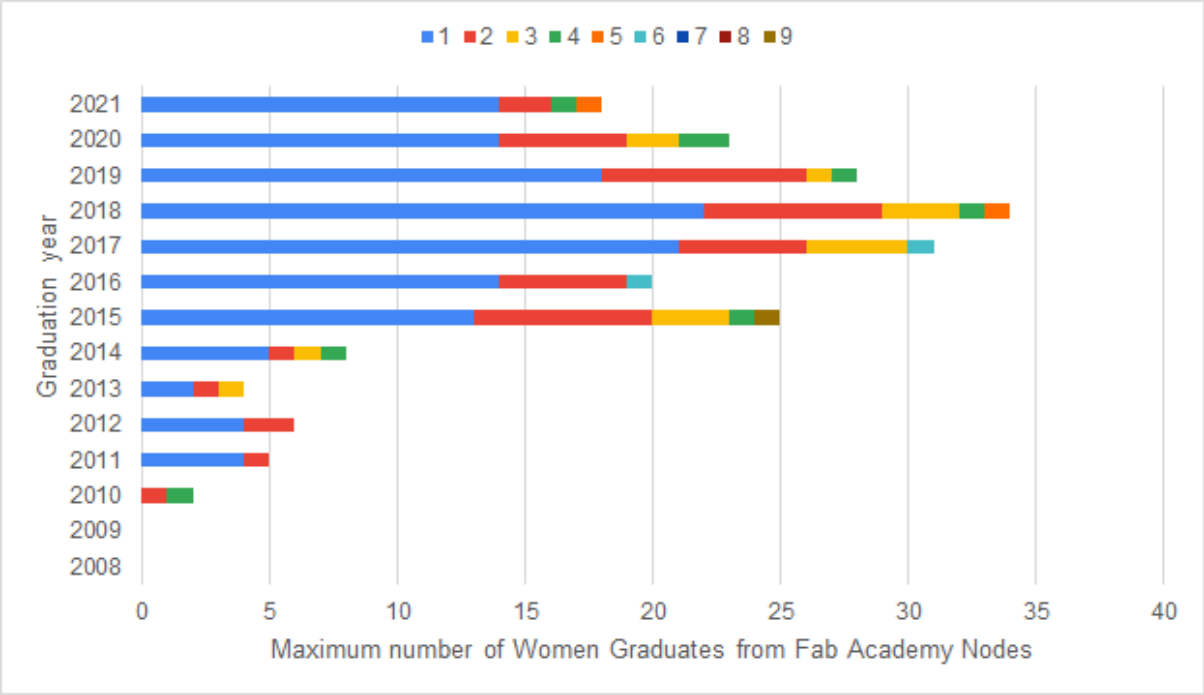

Figure 7: The maximum number of women graduates in Fab Academy Nodes (Authors)

We analyse the number of women graduates by Fab Labs (Fab Academy Nodes), in order to identify the particularity between the numbers of graduates in a specific learning space. We show (Fig. 7) the Fab Academy Node graduation year relationship represented on the Y-axis. On the X-axis, we show the maximum number of Fab Academy Nodes in relation to the number of women graduates. The growth curve of graduates by Annual Fab Academy Graduation Ceremony, increased since 2010, but when analysing the number of women graduates by Fab Academy Nodes during the 13 years, we found that the thirteen Annual Fab Academy Graduation Ceremonies would be equivalent to 204 Fab Academy Nodes Graduations. Here, the women graduates do not represent a high presence. 131 Fab Academy Nodes at least show one graduated, 45 Fab Academy Nodes had 2 graduates, 15 Fab Academy Nodes with 3 graduates, 8 Fab Academy Nodes with 4 graduates, 2 Fab Academy Nodes with 5 graduates and 1 Fab Academy Node with 9 graduates in 2015 from Fab Lab Barcelona.

5.2 Presence of women in the Fab Lab Research Papers

Of the 123 papers published between 2012 (FAB8) and 2019 (FAB15), 54 (44%) papers correspond to female authors or co-authors. Dividing the total number of papers published by women, 41 papers correspond to a female main author and 13 papers correspond to a co-authorship, where the main author was male. The first article in which a woman participated was co-authored by Betty Barrett in FAB8 in 2012 with Virginia McCreary, also a co-author. The first article by a woman as the lead author was by Anna Waldman-Brown on FAB9 in 2013.

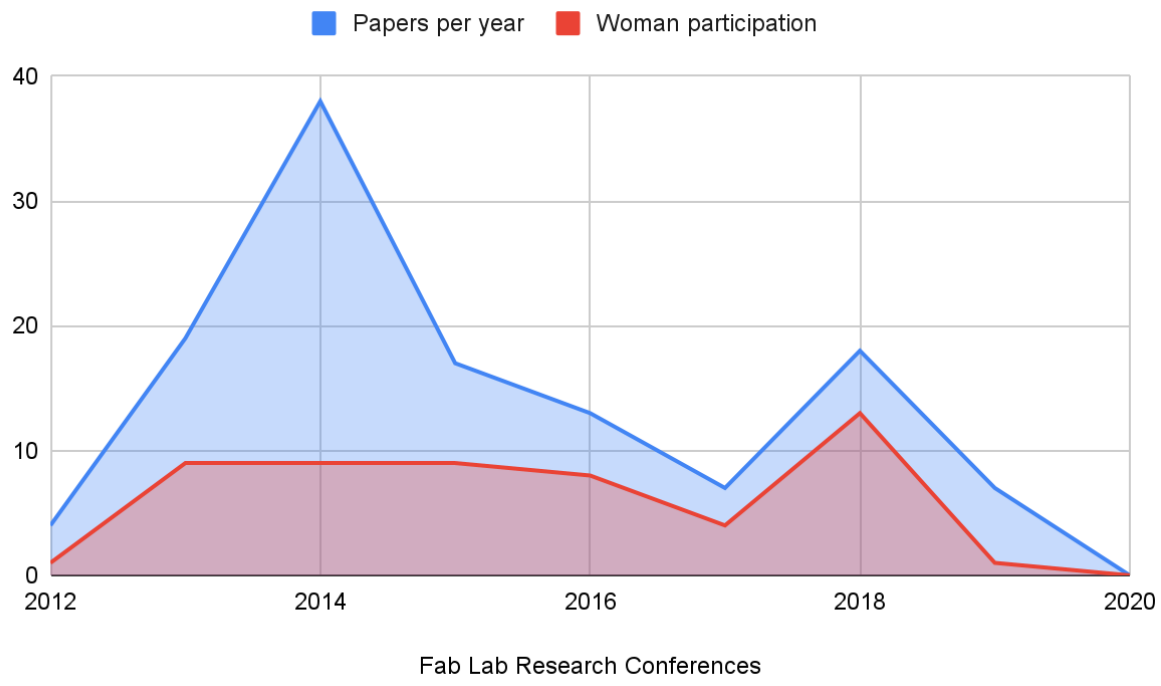

Figure 8: Participation of female authors in the Fab Lab Research Conference between 2012 and 2019. (Authors)

Unlike the participation of women in the Fab Academy, the presence in the publication of scientific papers is much higher (Fig. 8). Being the average participation in 8 years of 44% that reached a presence of 73% in 2018.

6 Discussion

The Global Gender Gap Index 2020 (World Economic Forum, 2019) estimates that the time needed to close the gap between women and men in the sub-indices of employment, education, health, and politics is 99.5 years. In education, this gap is projected in 12 years.

In this research, we reveal the presence of women in two specific scenarios promoted by the Fab Foundation: the Fab Academy between 2008 and 2021 and the Fab Lab Research Papers between 2012 and 2019. In both contexts, the presence of women does not It is fortuitous or accidental, but reveals some aspects that characterize the Fab Labs project-based learning model. It does not differentiate gender but enriches it through imagination, play, sharing, experimentation, prototyping, socialization, and exchange in STEM. The problem-based learning model is projected to Fab Lab based learning as an inclusive response that facilitates closing gender gaps in less than a decade.

Fab Academy statistics indicate the percentage distribution by gender of applicants. This research presents data from Fab Academy graduates as well as the presence of female authors in two contexts that are part of the Fab Labs ecosystem. These contexts reveal two important aspects to discuss.

The first aspect shows that the learning model presents participation percentages higher than 20% above other STEM contexts. However, this percentage is minimal when we review the number of women graduates from Fab Lab. We show a geographic representation (Fig. 9) with two specific cases (USA and Spain). This is a relevant point to consider if the participation of women graduates is expected to increase in the future.

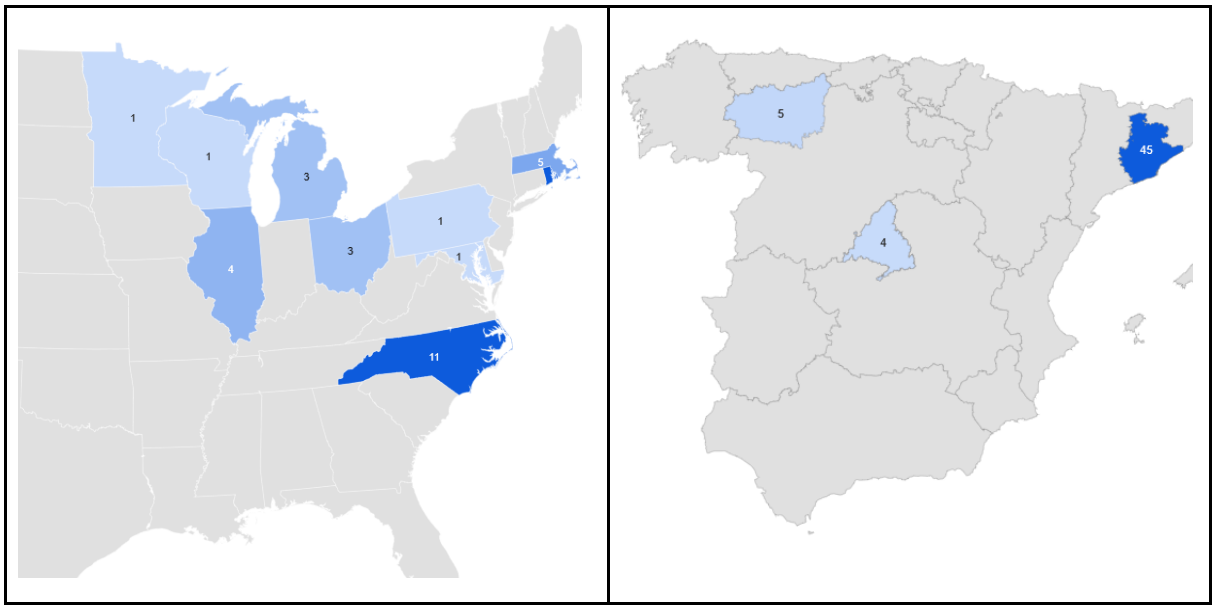

Figure 9: Number of women graduates in the USA by State and Spain by Autonomous Communities between 2008 and 2021. (Authors)

The second aspect to discuss refers to the presence of women who published papers in the Fab Lab Research. The percentage of female authors close to 50% reveals a timely gender balance for the Fab Labs community. This scenario is not very different when we review the publication of important books by women in the last 8 years: Julia Walter-Herrmann and Corinne Büching (2013); AnnMarie Thomas (2014); Camille Bosqué, Ophelia Noor, Laurent Ricard (2015); Kylie Peppler, Erica Rosenfeld and Yasmin B. Kafai (2016); Sara Davies (2017); Elizabeth Garber, Lisa Hochtritt and Manisha Sharma (2019). All these references, reveals the interest of women in making visible the ecosystem of Makers, Fab Labs, and Educators. A future review of literature, themes, and topics in other contexts, such as the FabLearn leaded by Paulo Blikstein and other Fab Labs references, would complete important aspects of a new research.

Although we include review of reports, analysis of websites (information texts, photos, pictures, student's interviews, and Fab Foundation database), we believe it is relevant that qualitative data are added to our quantitative data to analyse gender in Fab Labs, regarding the role and participation of women in their processes (Berge et al., 2019). We also suggest considering include social media aspects, based on the work of Eckhardt et al. (2021) for the future research of gender in Fab Labs.

7 Conclusions

The analysis of the current state is a valid methodology to analyse every year the presence of women in the Fab Lab ecosystem. From 1191 records (Fig. 1) in thirteen years (2009-2021), we analysed the distribution of 329 women (Fig. 3) with respect to the number of male graduates (Fig. 4) including place of graduation (Fig. 5), who graduated annually from 104 laboratories located in 42 countries (Fig. 6). In a more specific analysis, the 13 years can be divided into 204 graduations promoted by each Fab Academy Node. In these graduations, we found that 64% from Fab Academy Nodes had only one female graduate, 22% two graduates, 7% three graduates, and the percentage decreased until a maximum of six female graduates in two Fab Academy Nodes (Fig. 7), with a single case of nine female graduates in 2015 from a Fab Academy Node.

The percentage results of the Fab Academy were different in the Fab Lab Research Papers (Fig. 2). The range of years (2012-2019) showed a variable percentage of papers with women authors, with a minimum presence of 14% (2019) and a maximum of 72% (2018), with an average presence of 44% in the range analysed (Fig. 8).

The results show the impact of the Fab Lab´s ecosystem, including interest in the Fab Academy model with workspaces and co-design regardless of gender and with Research Conferences promoting flexible and adaptable topics for inquiry by design. This coexistence allowed more women to stay in the Fab Lab's ecosystem after validating a curiosity and exploration for science, by becoming an important daily partner of their processes. In this way, we can aim for sustainable lifelong learning, enforcing the love for science.

Acknowledgement

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