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# Early Stages of the Fablab Movement: A New Path for an Open Innovation Model

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**Abstract:** FabLabs, also known as digital fabrication laboratories, are a groundbreaking phenomenon that is contributing to the democratization of innovation and technology. Despite their potential influence, this emerging area has received little attention in the literature. This paper examines the initial stages of the FabLab movement using a mixed-sequential exploratory methodology. Qualitative methodologies were employed to identify relevant dimensions and establish research hypotheses, while quantitative methodologies were used to evaluate and validate these hypotheses and generate a predictive model for the innovation process through binary logistic regression. The information obtained through the participation of 124 laboratories in the online FabLab Global Survey was used. The results indicate that collaborations with large companies and a majority focus on research in FabLab projects promote the development of innovative projects compared to those laboratories affiliated with educational institutions or primarily used by students.

**Keywords:** FabLabs; open innovation; collaborative platforms; technological prototypes; sustainable innovation

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## 1. Introduction

Innovation, as an element supporting the generation of new products and technologies, has undergone an interesting evolution in recent decades. Its classic conceptualisations defined it as a mechanism encompassed in business activity. This classic conceptualisation showed a lack of infrastructure necessary for the inclusion of external processes, which disassociated the company from the social contribution and prevented the end user and recipient of the product of its activity from participating. Social evolution and advances in communication systems and technology—which have gradually abandoned the well-known Digital Divide to discover an era of robust social interconnectedness, thanks to the Internet and the steady growth of social networks—have become a favourable environment for the new generation of user communities that are grouped according to their similar cultural and social characteristics as well as their diverse joint interests. This strong social change should not be ignored by business activity.

It is in this new social environment where the sharing of knowledge and information takes on special importance, generating a new knowledge-based economy where the distribution, production, management, and use of such information and experience emerge as the basis of its functioning [1], highlighting the importance of the efficient use of all types of knowledge throughout all processes of activity [2].

As indicated by the European Commission [2], this evolution of the economy is based on four main factors: the extraordinary advance of the abovementioned information and communication technologies, the accelerated speed of technological and scientific advances, the growing global competitiveness provided by the reduction of communication costs and the ever-increasing demand associated with the increased revenues, and changes in attitudes and preferences related to social prosperity. Moreover, and about this aspect, there are three changes that the European Commission associates with knowledge as economic momentum in today's economies:

- Knowledge has turned into another product that can become an active subject for negotiation.
- The cost associated with knowledge gain and transfer has been drastically reduced, thanks to the advances in the information and communication technologies.
- The interconnectivity level between the agents involved in the generation and knowledge management has increased in an exacerbated manner.

An important aspect that is nourished by this approach of technology to society is the proliferation of community environments where knowledge and technological skills are shared. These environments include social ecosystems such as Hackerspaes, Makerspaces and FabLabs, which have become places for dissemination, learning, and exchange of experiences, allowing for a wider democratisation of technology.

Thanks to Neil Gershenfeld, FabLabs emerged in 2001 in the CBA (Center For Bits and Atoms) from the MIT (Massachusetts Institute of Technology) as part of the cross-curricular subject "How to Make (Almost) Anything." They are rapidly disseminated throughout the planet as empowerment and social transformation elements that are highly appreciated, especially in educational environments [2–5]. FabLabs, as with other elements of the Maker movement, base their structure on collaboration and other factors, such as peer production, taking advantage of open knowledge distribution, the local and global networks that they establish [6], and the democratisation of the productive processes characteristic of the digital manufacturing [7].

Thus, the technology and knowledge available in the different Maker environments constitute a tool that allows the user to approach and understand technological development in a practical way. They also allow them to approach manufacturing processes and tools that they would not be able to acquire on their own and for which specific training would be necessary. This approach sometimes leads to the generation of new business initiatives or collaboration with entities and companies in the development or improvement of a product. The adoption of this type of ecology as an active element in the innovation processes of companies today represents a change in the classic paradigm and enables the development of more participative technological products.

### *1.1. The Concept of Innovation*

At this stage, it is necessary to define the concept of innovation, although this has evolved outstandingly in the last five decades (see Table 1). If we consider its first conceptions, innovation was viewed as the cautious development obtained as a result of the studies of individual researchers [2], a definition that, nowadays, has become thoroughly obsolete and it is considered necessary to open a new reference framework. Thus, it is easy to see how the meanings of innovation reflect an increasing openness to external processes to companies and indicate a growing relevance of social aspects in these processes [8,9]. Different phases in the theoretical contextualisation are identified, which, starting from the initial conceptualisation as innovation derived from science and scientific knowledge—formally called technological impulse—approach models focused on innovation linked to social environments. However, once again, there are several classifications and models that can be found in the scientific literature [10], and the name provided by the European Commission in its report identifies, in summary form, five significant stages [2], reinforcing the open evolution of the concept:

- Innovation derived from science (technology push).
- Innovation derived from market requirements (demand driven).
- Innovation derived from connections between market players.
- Innovation derived from technological networks.
- Innovation derived from social networks.

**Table 1.** Evolution of the definitions of innovation. Our own work, based on Landry, Amara, and Lamari, (2002) [11].

| | |
|---|---|
| Dosi, 1982 [12] | A particular process of the problem resolution property of the company. |
| Cohen and Levinthal, 1990 [13], Dogson, 1991 [14] | A varied and diverse learning process in which internal and external sources of knowledge are included as well as the absorption capacity of themselves from the companies. |
| European Commission, 1995 [15] | The renewal or update of the range of products and services offered by companies, the creation of new production models, and the implementation of changes in the work management or organization. |
| Kline and Rosenberg, 1986 [16] | A formal and informal interactive process that involves interactions between companies and commercial networks with different participants from the company's environment. |
| Chesbrough, 2003 [17] | A temporarily cyclical process in which the previously obtained benefits are invested to enhance the development of its products, which, in turn, are protected by restrictive intellectual property policies that allow the company to create new features or its new products. |
| Acs, 2000 [18] Edquist, 1997 [19] Landry and Amara, 1988 [20] Porter, 1998 and 2000 [21,22] Teece, 2004 [23] | A process that occurs mainly in commercial companies where the contribution of government agencies and public research institutions is kept on a minor scale. |

The first of these are referred to as linear models. The technology push model is considered as a first-generation model and shows an established but not clearly defined theoretical background [24,25], although some authors, such as Mirowsky [26], attribute it to Samuelson. In the case of the demand-push or second-generation model, innovation is considered as a single, linear process in which a conversion from inputs to outputs takes place following a series of concrete steps [25,27] and is shown to be essential for industry research and development. It is necessary to point out that, although in the case of the technological impulse model, research and development were the initial source of the process, and it was an internal process. Nevertheless, in the case of the demand push, the external pressure is considered as an active incentive of its generation [10].

In models derived from actor–actor connections or chain models [16,28], the connections between the market and knowledge are not as automatic as the previous models [11]. In them, we focus on the possible connections between research and the market through production, engineering, technology development, and marketing, as highlighted by Mowery and Rosenberg [29] and Landry and Amara [11]. From the 1980s, this model began to value the increased importance of the information obtained from the contact processes between companies and customers [2,30]. Thus, the external data started to gain increasing importance with the required technology for the exchange in the same way that it gives rise to the real Innovation Systems [31,32] based on the importance of the new external agents' intercommunication, which will include clients, advisors, suppliers, universities, governmental research laboratories, etc. [11]. In this way, the classic innovation models are gradually abandoned, where the internal research and development departments were in charge of producing the knowledge that was managed actively through the company's control over intellectual property.

This type of practice generated a high number of potentially fruitful projects that were abandoned because they did not belong to the main line of work [33]. Permeable models allow for a more meaningful exchange of inside–outside information with greater availability and a higher overall speed of transfer, allowing knowledge to come from a wide variety of actors [33]. These models include the premise that innovation is based on the initial determination of research (a nod to the theory of technological momentum) for interaction between firms and other actors (the theory of technological networks), but with the nuance that it is knowledge that actually promotes innovation through the accumulation of actual technical expertise and its simple accessibility [2]. In this way, the information would be transformed into knowledge through the convergence of data from a wide variety of actors who, in turn, share it quickly. Innovation will be a result from the combination of different tangible capital demonstrations with the intangible forms of disorderly capital and the respective interactions between companies and the external actors [11], thereby representing a new paradigm that abandons the concept of innovation closed to the company [17].

### 1.2. Open Innovation

The traditional approach understands innovation as an asset of the firm that is an effective barrier to entry, preventing the small business sector from entering because it cannot afford costly and robust research and development departments—-a conceptualisation that reinforces the value of innovation based on the generation of protected products with significant intellectual property restrictions, and where external actors were not allowed access [17]. In contrast to this classic paradigm, the concept of open innovation includes multiple sources of information that are integrated into the company's own processes. These processes include, among others, the acquisition or participation in initiatives of interest external to the company itself, as well as the free or conditional exchange of information with other elements or the collaborative and parallel development of new products and services [34,35].

According to [36], sustainable development practices serve as the basis for any context in which humans and the environment meet. These innovations will underpin sustainable development by relying on networks, local communities, and corporate sustainability as think tanks that develop benign solutions to societal challenges. This is relevant to understanding the innovation ecosystem, which comprises a multi-layered framework in which institutions interconnect to develop and share information and knowledge necessary for the development of new innovation processes. Open innovation can therefore enhance sustainable innovation ecosystems and drive the digital transition.

The paradigm shift includes the adoption of premises such as the existence of human capital and knowledge superior to the firm's external expertise, the consideration that research and development from outside the firm can also be of significant value to the firm and can be guided by its research, or the elimination or mitigation of intellectual property restrictions by allowing the use of its development by external elements for the benefit of the firm. Thus, this new concept of innovation, where the boundaries of the firm are shifted in the research and development process from inside to outside and from outside to inside in a permeable way, is known as Open Innovation [17]. Open Innovation is not an unfamiliar process, as the scientific literature has been documenting its popularity in industrial settings since the beginning of the century. Environments such as digital fabrication laboratories or FabLabs and communities such as Maker communities have taken a step forward in innovation, shifting industrial development from the business realm to a more popular sphere, involving users with low or no theoretical and technical knowledge, but with a great ability to contribute and learn through participation in projects. The popularization of these new collaborative environments and ecosystems still lacks sufficient attention in the scientific literature, and due to its relevance and interest, it sparks a natural curiosity that translates into relevant documentation for further study in the field.

### 1.3. FabLab and Innovation

This work focuses on FabLabs: Fabrication Laboratories, where almost any object can be manufactured from its initial conceptualisation to its complete physical realisation [37,38] and which includes specific and advanced elements for digital fabrication, such as laser and CNC cutting machines, 3D printers, microelectronics elements, or open source software and hardware applications. FabLabs provide open access to highly specialised technologies and knowledge, allowing a process from the development of ideas and prototypes to distributed manufacturing, both for personal and commercial purposes [3,38,39].

The activities carried out in the FabLab usually have an impact on the technological empowerment of its participants, including training users to develop complex projects with their own digital manufacturing technologies in co-creation or group creation processes, increasing the end user's innovation capacities [7,38,40], and even becoming promoters of entrepreneurship [41,42]. The ability to provide new competences to their users means that in many cases they are integrated into training institutions, providing students with a new frontier in the development of their projects and activities [43,44].

The integration of FabLabs within educational institutions can be carried out in two main ways: direct integration in which the FabLab is generated and depends exclusively on the educational institution, providing services to its students and users on a priority or exclusive basis, or partial integration in which the laboratories are independent entities that collaborate with the educational institutions, providing their services to their students. Despite the potential that FabLabs has in the educational environment, there are few cases of FabLabs integrated into primary and secondary school services, with FabLabs integrated into university educational institutions being more common. The users in these educational environments are therefore usually undergraduate and postgraduate students who acquire technical training for the development of their projects.

The FabLabs also have their own distributed training programme, the FabAcademy, which has been developed internationally and has trained around 1000 students since its inception in 2008. This training programme is taught exclusively in FabLabs that meet a series of sufficient technical and human requirements, becoming Nodes [45].

On the industrial and business side, the development of projects in the FabLab environment has been identified in the scientific literature as an innovation-stimulating activity that includes significant value creation for the company thanks to the knowledge and tools characteristic of these spaces [46–49].

Several companies include FabLab spaces in their processes as an additional activity for their employees and as a complement to the classic innovation processes developed by the research and development departments. Cases including Renault, where, with the intention of promoting and stimulating the company's innovation practices by bringing them closer to the employees on the production line, the Renault Creative Lab was created, and also the FabLab that the company Saint-Gobain manages in Bristol, complement the list of laboratories included in companies such as Air Liquide or EDF [50–53]. These FabLabs, despite their name, do not share the initial philosophy of the FabLabs set out in the FabLab Chartre, which includes values such as openness to the public and the development of their activity by integrating a global network of laboratories [54–56] and are not part of the global FabLabs network. Other initiatives include collaboration with local FabLabs and Makerspaces, such as those carried out by Ford and Siemens, reinforcing the importance of FabLabs as social environments. In these cases, the exchange of knowledge is richer by including actors external to the company process.

Despite the importance of the social and technological processes involved in them, and their popularity and diffusion across the planet, the impact in the current scientific literature is still scarce [57], which further motivates the development of studies such as the present one.

The impact of the FabLabs network is a growing phenomenon that, since its inception in 2001, has grown from over 1200 labs in 2017 to close to 2000 FabLabs today, with a presence in 120 countries around the world [58]. Although their typologies are varied and their characteristics are changing, many do not find the business model that allows them to achieve the necessary sustainability to remain active. This fact causes many of them to disappear or to reorient their activities and services in order to survive. After almost twenty years since their creation, there is no defined and stable economic model to guarantee a certain degree of stability, which makes it particularly important to study the success stories that have reached us today.

This study evaluates the capacity for innovation present in the projects developed in FabLabs, based on the characteristics, users, and level of FabLab staffing and equipment in the early stages of global expansion, considering those that have managed to sustain themselves economically up to the present day.

## 2. Materials and Methods

The low scientific impact that the FabLab phenomenon [57] has and the evident lack of proven theoretical models on which to base the rigorous research encourage us to approach our work in order to provide a better understanding of the Innovation processes within FabLabs through a double methodology: qualitative and quantitative (Figure 1). Therefore, research design will be used to adapt to the combined sequential exploratory model [59,60].

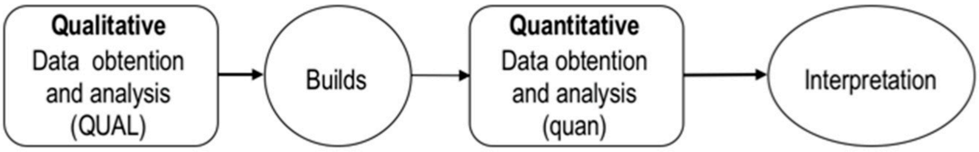


**Figure 1.** Design of mixed sequential exploratory method (Creswell, 2017 [60]).

As depicted in Figure 2, the investigation is structured into two phases. Phase I consists of three components, encompassing the collection and qualitative examination of data to establish the dimensions upon which to construct the measuring instrument. This phase entails the implementation of qualitative methodologies to gather data from three sources: (a) a literature review, (b) a Focus Group, and (c) semi-structured personal interviews, followed by analysis with the utilization of the Nvivo10 tool and triangulation techniques to determine the dimensions that will serve as the basis for the construction of the FabLab Global Survey measuring instrument.

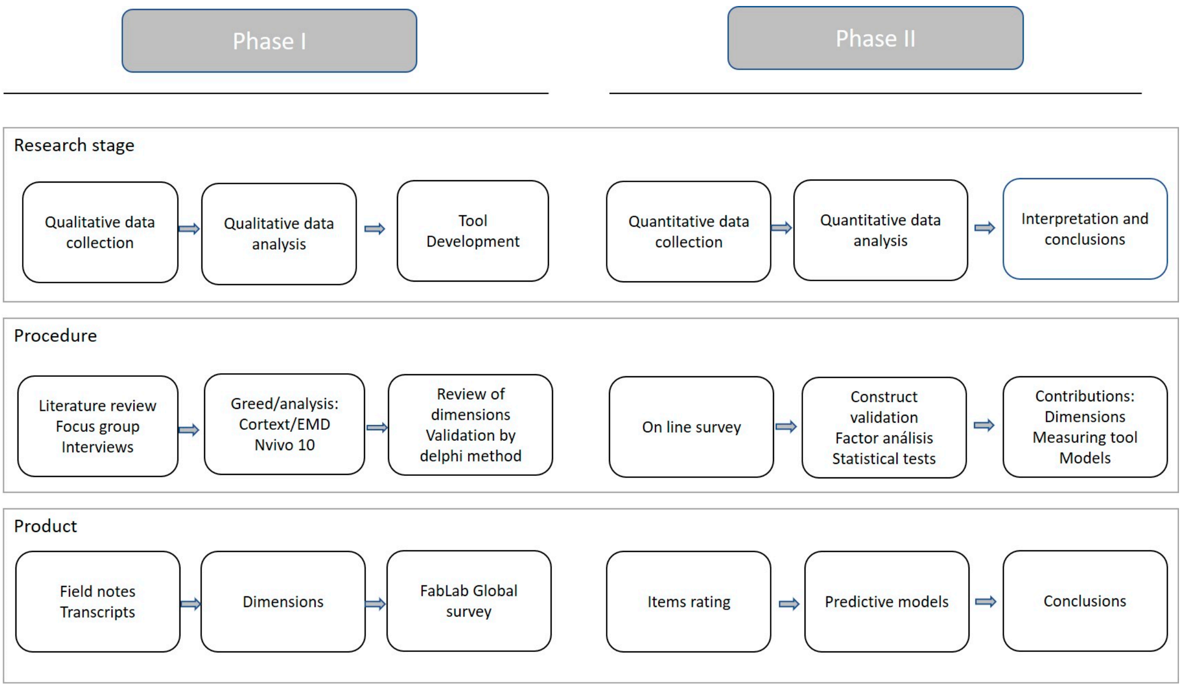


**Figure 2.** Research development.

Based on the dimensions identified in this phase, the measuring instrument is developed, and the necessity to design a validation tool using the Delphi method is contemplated. Once the questionnaire's aptness has been authenticated, we proceed to Phase II, which encompasses the online dissemination of the FabLab Global Survey among the FabManagers, and its analysis using the SPSS statistical programme to generate models on the dimensions identified in the previous phase, as well as the final model on the business models of the FabLabs. Throughout all research phases, special attention is given to ensure the validity and reliability of the resulting data.

The present study conducted a comprehensive literature review using major bibliographic databases with a wide scope within the scientific community. The aim was to undertake a bibliographic analysis of the documents available in these databases, examining their fundamental typologies, main themes, and distribution over time. An initial classification was established based on document type (e.g., article, press publication, communication, other) and typology (e.g., theoretical, case, descriptive, or application). Subsequently, the bibliographic corpus was generated from the previously collected data and analyzed using various tools to identify the primary concepts related to the FabLab concept. The study followed a dual approach, as depicted in Figure 3, to accomplish the proposed objectives.

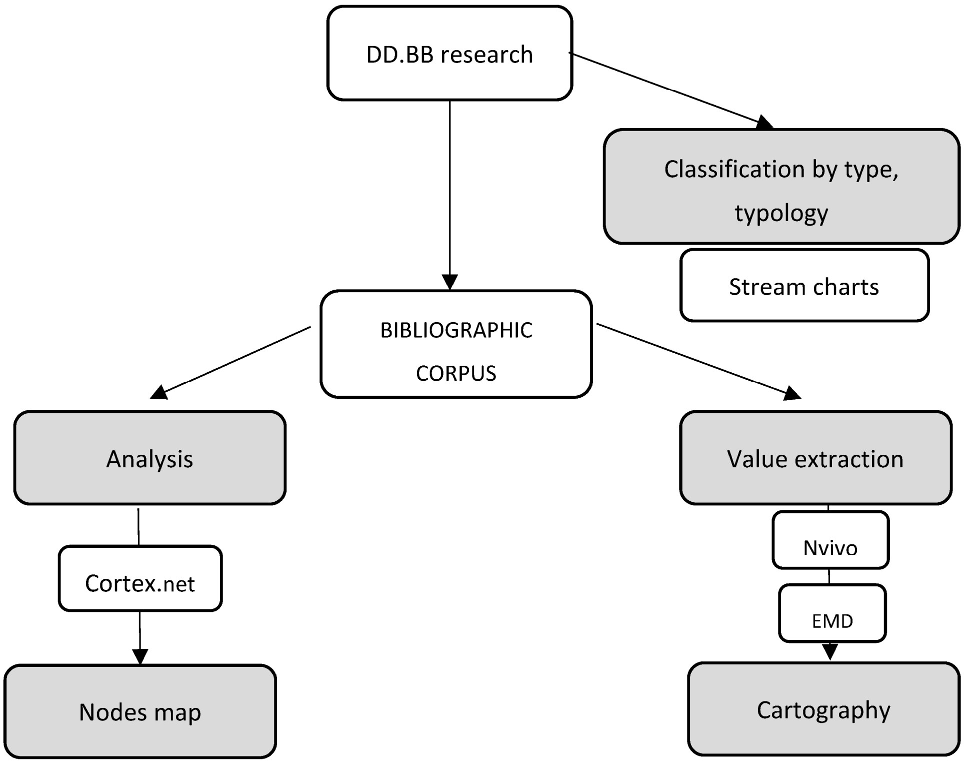


**Figure 3.** Working diagram.

The study is intended to present an approach that leverages multiple sources of information to generate and refine pertinent knowledge, leading to the emergence of nascent theories in contexts where preexisting theories are sparse. Specifically, we conducted a comprehensive literature review, culminating in the identification of several key themes such as rapid prototyping, additive manufacturing, architecture, innovation, and their broader societal and economic implications. We proceeded to scrutinize these themes in greater depth, eventually distilling them into five overarching thematic nodes: constructive sustainability, educational processes, digital manufacturing processes, collaborative innovation, and new business initiatives.

To further advance in the investigation, we utilized a Focus Group methodology, which enabled us to obtain a series of informative and generalizable dimensions to characterize the FabLab phenomenon. These dimensions encompassed a broad spectrum of pertinent aspects, ranging from physical characteristics of a FabLab to perceptions of digital manufacturing and educational processes, as well as economic and sustainability considerations, social factors, innovative features, and documentation procedures. The dimensions thus identified represent a crucial foundation for future research aimed at deepening our understanding of the FabLab phenomenon.

These main dimensions, extracted from the qualitative analysis of the transcription of the Focus Group, were validated by conducting the first personal interviews where, based on the analysis of their transcriptions, five relevant approaches were identified that, in the opinion of the research group, serve as a starting point to delve deeper into the FabLab phenomenon:

- Documentation processes as elements of knowledge generation in FabLabs.
- The innovative processes developed in FabLabs.
- The independence and management of FabLabs.
- FabLabs as generators of new economic initiatives.
- The characterisation of the business model present in the FabLab.

Focusing on the field of innovation, the research question that gives rise to this paper is: What, if any, are the conditioning factors of the innovative processes in FabLabs?

In the following section, we will explain the construction of the selected problem question.

*Hypothesis Definition*

Based on the completion of in depth interviews with FabManagers and digital fabrication laboratory managers, we conducted various focus groups with managers, experts, administrators, and users in different cities with the presence of FabLabs, and reviewed the relevant literature. The main corpus of qualitative information was obtained to construct the dimensions that generate different hypotheses on which to support the quantitative model.

Innovation is often cited in the literature as an inherent activity in FabLabs, which are characterized as fabrication laboratories. However, it appears that not all activities in these laboratories are innovative. It seems that the particular focus of FabLabs on educational activities, whether as a complementary training or as a specific service, limits the development of relevant projects with high innovation potential, restricting their service to the practical application of their technology. For all these reasons, it leads to the following hypothesis (Table 2).

**Table 2.** Hypothesis construction.

| Main Assertions | From |
|---|---|
| *"There are several types of FabLab, [ ... ] but it is clear that those within a university and primarily dedicated to the university's students and their projects ... are unlikely to innovate much."* | Focus Group (May 2015) |
| *"Our FabLab is at the service of the university and its students, so innovation takes a back seat."* | FabManaager D.G. (October 2015) |
| *"The FabLab is just another tool of the University, in fact, it occupies the space of what used to be the Reprographics department ... among the printing plotters, and with the oversaturation of tasks, little innovation is taking place."* | FabManage F.S. (October 2015) |
| *"Innovation? Our innovation is providing students with fantastic tools, contributing to their education, contributing to knowledge ... "* | FabManager J.C.P.J. (May 2015) |
| *"The FabLab belongs to the University and serves its students [ ... ] in addition, we have been operating for a short time and no significant projects have been proposed yet."* | FabManager: S.K. (October 2015) |
| **Hypothesis I.1.** Innovation processes are influenced by the FabLab's primary dedication to educational environments. | |
| **H.I.1.1.** Innovation processes are influenced by the FabLab's dedication to educational processes. **H.I.1.2**. Innovation processes are influenced by the FabLab's dedication to students. | |

However, the presence of relevant projects dedicated to research or product development combined with research seems to imply a high degree of innovative development (Table 3).

**Table 3.** Hypothesis construction.

| Main Assertions | From |
|---|---|
| *"There are many cutting-edge FabLabs in innovation, but of course, they are dedicated to that, to innovation, to developing things . . . ."* | FabManager J.C.P.P.J (May 2015) |
| *"Serious innovation, the real one, is developed in important FabLabs, which are dedicated to that, which bring products forward . . . "* | Focus Group (May 2015) |
| **Hypothesis I.2.** The innovation processes are influenced by the FabLab's dedication to students | |

After analyzing the information, it appears that carrying out activities with a high degree of innovation can be influenced by the completion of relevant projects in collaboration with external entities or universities, as well as participation in joint projects with other FabLab laboratories (Table 4).

**Table 4.** Hypothesis construction.

| Main Assertions | From |
|---|---|
| *"Of course, when the FabLab channels the full potential of a university and does not exclusively focus on the students, that innovation occurs."* | Focus Group (May 2015) |
| *"We have several projects with important companies, innovative projects . . . "* | FabManager T.D. (October 2015) |
| *"When a large company participates alongside a FabLab, that's when you see that they are seeking true innovation, serious innovation, a change that they may not find in the usual processes of that Company"* | Focus Group (May 2015) |
| *Factors of innovation developed in a FabLab: collaboration with other laboratories.* | Focus Group (May 2015) |
| **Hypothesis I.3.** The innovation processes in FabLabs are influenced by joint participation in project development. | |
| **H.I.3.1.** The processes of innovation in FabLabs are influenced by joint participation in projects developed with other laboratories.<br>**H.I.3.2.** The innovation processes are influenced by the joint participation in projects developed in universities.<br>**H.I.3.3.** The processes of innovation are influenced by the participation in joint projects with large companies | |

The hypothesis obtained through the formal and methodological analysis of the qualitative corpus constitute, therefore, our set of formal hypotheses to generate the quantitative predictive model (Table 5).

**Table 5.** Hypothesis: The innovation processes present in the FabLab.

| |
|---|
| **Hypothesis I.1.** The innovation processes are influenced by FabLab's priority dedication to educational environments. |
| **H.I.1.1.** The innovation processes are influenced by the FabLab's dedication to the educational methods. |
| **H.I.1.2.** The innovation processes are influenced by the FabLab's dedication to students. |
| **Hypothesis H.I.2.** The innovation processes in the FabLabs are influenced by their dedication to research and development projects. |
| **Hypothesis H.I.3.** The innovation processes in the FabLabs are influenced by the joint participation in the project's implementation. |
| **H.I.3.1.** The innovation processes are influenced by joint participation in projects developed with other laboratories. |
| **H.I.3.2.** The innovation processes are influenced by the joint participation in projects developed in Universities. |
| **H.I.3.3.** The innovation processes are influenced by joint participation in projects with large companies. |

Additionally, we conducted semi-structured in-depth interviews with managers, lab technicians, officials, and directors of digital manufacturing labs, which provided a more nuanced understanding of the day-to-day operations and challenges faced by these labs. The qualitative information generated through the analysis of these sources allowed us to develop several hypotheses on the factors linked to the development of innovation projects in FabLabs. The use of software for the management and analysis of qualitative data enabled us to extract commonalities of information that served as the foundation for the construction of these hypotheses.

In summary, the first stage of the project played a crucial role in setting the foundation for the subsequent stages, which involved the quantitative validation of the hypotheses and the development of a predictive model for the innovation process in FabLabs. By combining insights from the existing literature, focus groups, and in depth interviews, we were able to identify key factors that influence the success of innovation projects in digital manufacturing labs and develop hypotheses that were validated in later stages of the study.

## 3. Results

In the second stage of this work, the previously stated hypotheses were validated by means of the quantitative information obtained from the application of the questionnaire and a predictive model was generated. For this quantitative information, we used the information from the international FabLab Global Survey questionnaire [61], which had been validated in three languages—-Spanish, English and French—-and had 40 questions grouped into three large blocks:

- Block I: Descriptive data to the main characteristics of FabLab.
- Block II: Description of the business model.
- Block III: Focused on innovation processes and documentation in the FabLab.

The questionnaire was distributed electronically via e-mail to the heads of the FabLabs in two waves, in which the laboratories that had not replied were asked to collaborate on a new occasion 1 month after the first wave had taken place. As a result, 124 FabLabs participated out of the 445 that were initially considered accessible by showing their contact in the request, representing an overall response rate of 27.9%. Nevertheless, due to the rapid growth of FabLabs and the size of the sample, the results of the present analysis should be treated with caution.

In order to quantitatively validate the hypotheses put forward, the relationship established between the quantitative independent variables from the questionnaire shown in Table 3 was evaluated. As a dependent variable, the existence of a high percentage of projects linked to innovation developed in the FabLab was estimated, considering this to be the case when the percentage is higher than 50% of the projects carried out in the laboratory (Table 6).

**Table 6.** Evaluation of the hypothesis through contingency tables: results Variable (Y/N).

| |
|---|
| The main contribution of the FabLab is oriented towards education. |
| Current FabLab users: mainly university students. |
| The FabLab's main contribution is its focus on research and product development. |
| Existence of projects developed with the FabLab Network. |
| Existence of projects developed with university institutions. |
| Existence of joint participation in programmes with large companies. |
| High percentage of innovation projects developed (more than 50% of the projects). |

For this validation of the hypotheses, it was considered relevant to use Contingency Tables, a statistical technique that applies the cross-tabulation of the data of the independent and dependent variables, which makes it possible to measure the association existing between them and the evaluation of the significance of this association. In the use of Contingency Tables, the Phi statistic is considered, which makes it possible to evaluate this degree of association between the variables—especially in the case of $2 \times 2$ tables—with its calculated value ranges between 0 and 1. Finally, the significance of the applied statistic is evaluated through the Pearson Chi-Square test (Pearson $\chi^2$), the importance of which will make it possible to accept or reject the hypothesis of independence raised [62], as shown in Table 7.

**Table 7.** Evaluation of the hypothesis through contingency tables: results.

| H | Variable | Pearson $\chi^2$ | $p$ | Phi | Evaluation |
|---|---|---|---|---|---|
| H.I.1.1 | Va | 6.247 | 0.012 * | −0.271 | Accepted |
| H.I.1.2 | Vb | 7.815 | 0.005 ** | −0.303 | Accepted |
| H.I.2 | Vc | 17.278 | 0.000 ** | 0.451 | Accepted |
| H.I.3.1 | Vd | 0.358 | 0.550 | - | Rejected |
| H.I.3.2 | Ve | 0.471 | 0.492 | - | Rejected |
| H.I.3.3 | Vf | 6.821 | 0.009 ** | 0.283 | Accepted |

* $p < 0.05$, ** $p < 0.01$.

Once the hypotheses were validated, the predictive model was proposed through the application of a Binary Logistic Regression in which those variables that showed a significant relationship were included. Binary Logistic Regression is a statistical data analysis technique commonly used to relate a binary dependent qualitative variable to one or more variables considered independent. Binary Logistic Regressions use the value ratio or the odds ratio—Exp (B)—as a measure of the magnitude of the association between the dependent and independent variables, meaning a positive and direct relationship when its value is greater than one and a negative or inverse relationship when its value is less than one. The absence of a relationship between the variables would be indicated by an odds ratio value equal to one [62].

## 4. Discussion

From the results shown in Table 3, we can affirm that the existence of a high rate of projects linked to innovation (a percentage of over 50% of the projects implemented in the FabLab) is favoured when the main dedication of the laboratory is focused on research into the digital manufacturing process, as well as when collaborative environments are produced or promoted in the implementation of the project with the participation of large companies. We can also verify that the inclusion of students in FabLab activities or the priority dedication of the FabLab to educational tasks act to reduce its capacity for the implementation of innovative projects. On the other hand, the data allow us to rule out the influence of carrying out projects jointly with other laboratories in the network and carrying out projects jointly with exclusively university institutions.

After verifying the hypotheses shown initially, the explanatory model through a binary logistic regression was proposed where, after discarding the possible effects of multicollinearity between variables, the summary of which is also indicated in Table 8, the primary variables that showed a correlation in the previous analysis by contingency tables are included.

**Table 8.** Binary logistic regression for the INNOLEVELBIN variable.

| | | | | | | | I.C. 95% for Exp (B) | |
|---|---|---|---|---|---|---|---|---|
| | B | E.T. | Wald | df | Sig | Exp (B) | L | H |
| Vf (H.I.3.3) | 1.519 | 0.671 | 5.116 | 1 | 0.024 | 4.566 | 1.225 | 17.022 |
| Vb (H.I.1.2) | −1.962 | 0.820 | 5.721 | 1 | 0.017 | 0.141 | 0.028 | 0.702 |
| Va (H.I.1.1) | −2.419 | 0943 | 6.581 | 1 | 0.010 | 0.089 | 0.014 | 0.565 |
| Vc (H.I.2) | 3.032 | 0.858 | 12.494 | 1 | 0.000 | 20.741 | 3.861 | 111.430 |
| Constant | 0.251 | 0.991 | 0.064 | 1 | 0.800 | 1.286 | | |
| $\chi^2_{\text{Hosmer-Lemeshow}} = 4.531$ ($p = 0.476$) | | | | | | | $R^2_{\text{Cox \& Snell}} = 0.364$ | |
| Omnibus Test: $\chi^2 = 38.499$ ($p = 0.000$) | | | | −2Log Probability = 62.678 | | | $R^2_{\text{Nagelkerke}} = 0.523$ | |

The proposed model allows the prediction of the existence or non-existence of the presence of a high implementation of innovation projects—more than 50% of the implemented projects.

The accuracy of the model was evaluated through the statistical $\chi^2$ by Hosmer–Lemeshow, verifying, in turn, its capacity for the 70.8% correct classification of positive cases and 88.5% of negative cases, achieving a total prediction capacity of 83.5% of the reported cases. Likewise, the model's overall decisive significance was assured through the Omnibus test $\chi^2$ = 38.499 ($p$ = 0.000). In this way, the resulting model was able to explain the 52.3% of the sample's total variance.

$$P(y=1) = \frac{1}{1+e^{[-0.251-1.519Vf+1.962Vb+2.419Va-3.032Vc]}} \tag{1}$$

In relation to the above results, and based on the odds ratio values obtained, we can affirm that a FabLab that collaborates with large companies will be 4.57 times more likely to offer a higher percentage of innovative projects than one that does not establish such collaborations. Likewise, a FabLab whose main contribution is research will be 20.74 times more likely to present innovative projects than those that do not. In the case of users, a FabLab whose main users are not students will be 7.1 (1/0.141 = 7.1) times more likely to present a higher percentage of innovative projects than one with this type of main user. Similarly, a FabLab whose main contribution is not education will be 11.23 times more likely to develop innovative projects than one whose main focus is education.

The probability that there will be a wide range of implementation projects considered as innovative within the FabLab will be conditioned by the independent variables that are involved in the model. In this way, we can affirm that the probability that this high incidence of innovation projects occur is low when the cooperative relationships with large companies are not established. The main contribution of the laboratory is not research but education, and its primary users are students ($p$ = 1.6%). Conversely, when cooperative relationships with large companies are established, the primary focus of the laboratory is on the digital manufacturing process research, but when students are not included among its primary users and the laboratory's dedication considered to the educational environments is not considered either, the probability increases to its maximum value ($p$ = 99.2%).

## 5. Conclusions

Innovation, as a process, has been conceptualised in different ways throughout the scientific literature, adopting different changing definitions over time. This goes from the consideration of innovation as a process of self-discovery carried out by large companies through which new products, goods, or services were produced or existing ones were optimised and evolved, and ones that were developed by their own departments and working groups and isolated from the primary production processes, all the way to the breakdown of the physical and virtual boundaries of the company for the inclusion of knowledge and methods of innovation in its production chain and the integration of innovation throughout its development.

Innovation, therefore, has evolved from an element that is close to the conceptual level to interactions such as open innovation where the boundaries of the company are blurred, allowing the input and output of knowledge, techniques, and technologies that help the generation and development of new products, goods, or services.

This permeability of the traditional boundaries of the firm is supported by the liberation of knowledge, partially departing from existing intellectual property protections, and by the contribution of knowledge elements beyond the boundaries of the firm and its usual procedures.

The advent of digital fabrication as a democratising process of manufacturing—thanks to the popularisation of technologies such as 3D printing, laser or numerical control cutters, or open hardware microelectronics—has meant, on the other hand, an essential growth in the knowledge of advanced manufacturing techniques in the general population. The influence of social movements such as the Maker movement is also noteworthy, in which one of the anchors is, precisely, the popularisation of projects and the exchange of knowledge between peers. This knowledge popularisation, reinforced by the proliferation of

Open-Source projects, involves the existence of an important source of information on the company's exterior about procedures that may be of interest. Within the Maker movement are FabLabs, which stand out for their strong social links and their obvious ability to contribute to the education of their users. Labs of this type have proven to be strongly linked to development and research in both educational and industrial environments. The characteristics of these digital manufacturing laboratories make them an essential support site for development activities related to innovation—understood as the development or improvement of new products, goods, or services—for both existing companies and start-ups.

In this paper, and based on the results obtained through the analysis of the information generated in the Global FabLab Survey questionnaire, we present the existence of several conditioning factors that modulate the current probability of the existence of a high percentage of implemented projects dedicated to innovation—over 50% of the projects carried out—in FabLabs. We have proposed an explanatory model based on a binary logistic regression to determine the probability of having a high percentage of implemented projects considered as innovation or associated with innovation. This model includes, as variables, the combined effects of the collaboration of large companies in the projects implemented in the FabLab, the main contribution of the FabLab to research projects, the main contribution of the FabLab to educational projects (a circumstance that would reduce the current probabilities of a high percentage of innovation projects), or the existence of the majority of laboratory users considered as students of external programmes (a circumstance that would also reduce these probabilities). The proposed model is characterised by its high predictive capacity. Thus, and taking into account the results, we can state that this probability increases when the implementation of FabLab activities includes the participation or joint collaboration of large companies, which is the main motivation of the FabLab in the implementation of its projects is research; when training or participation in educational environments is not one of the main motivations for its operation or is not considered as its main contribution; or when, despite the diverse range of possible users, the majority of users are not students of external training programmes. In this work, we also propose an explanatory model of the probability of presenting a high percentage of implemented projects considered as an innovation or associated with innovation, including the combined effects of the collaboration of large companies in the projects implemented in the FabLab; the FabLab's main contribution to research projects; the FabLab's main contribution to educational projects (a circumstance that would reduce the present probabilities of a high percentage of innovation projects); or the existence of most of the users of the laboratory considered as students (a circumstance that would also reduce that probabilities). Thus, the proposed model is characterised by high predictive capacity and an excellent adaptation to the Spanish case.

In relation to the above results, it is important to highlight the practical implications for FabLabs, companies, and innovation. FabLabs that establish collaborations with large companies and prioritize research in their operations are more likely to develop innovative projects. Therefore, it is recommended that FabLabs seek to establish partnerships with large companies to promote innovative project development. This can lead to a more productive and competitive environment for companies as well as potential economic benefits for the FabLab. For companies, the results suggest that collaborations with FabLabs may be a viable strategy for promoting innovation. By partnering with FabLabs that prioritize research and have a track record of developing innovative projects, companies can benefit from the knowledge and expertise of the FabLab community. This can lead to the development of new and innovative products or services, ultimately enhancing the competitiveness and sustainability of the company.

Innovation is critical to the growth and success of companies, and FabLabs can play an important role in facilitating this process. By understanding the factors that contribute to innovative project development, FabLabs can optimize their operations and increase their impact on the innovation ecosystem. The results of this study provide valuable insights for FabLabs and companies seeking to foster innovation and drive economic growth.

Therefore, we conclude by highlighting the relevance of collaborative environments and ecologies as enabling components of innovation, which are understood as part of open innovation. In these environments, it is essential to include Open-Source and Open-Hardware cultures and the growing evolution of the Maker and FabLab movements, which open the doors to the transformation of the user from a mere receiver of the product to a co-innovator user. This new participation of the user in the innovation process transforms him/her into a prosumer and allows him/her to participate in the final destination of the product. These ecologies emerge, particularly, as facilitating components of innovation in industrial environments where new forms of collaboration are required to improve competitiveness.

This study presents several limitations and future research directions. First, there is a growing scientific interest in FabLabs, which is primarily based on case studies and lacks theoretical development due to the novelty of the phenomenon. Second, the FabLab landscape is constantly evolving, particularly in economically unstable environments without a business model that ensures continuity, resulting in significant variations in their conditions and activities. Third, the high growth rate of the number of FabLabs resulted in a low response rate to the questionnaire, which limits the study's statistical significance and makes it challenging to construct a stable typology.

Despite these limitations, this study provides one of the most comprehensive investigations of the FabLab phenomenon, with significant participation from managers and directors of FabLabs, and one of the highest response rates to questionnaires in the scientific literature. Based on this information and documentation, several future research directions are proposed, including case studies of successful joint innovation projects with FabLabs, determination of the primary business models and economic sustainability required for innovation-oriented FabLabs, and precise characterization of the different types of FabLabs.

Although there are an increasing number of digital manufacturing laboratories that are being gradually integrated into industrial environments [63,64], a significant majority of them lack a clear focus on innovation and development. As a result, only a few of them have been featured in the scientific literature. However, it is important to note that there are some studies that delve into relevant aspects of digital manufacturing, such as innovation in hospital ecosystems [65]. These studies provide a strong foundation for future research, indicating that despite the current scarcity of research in this field, there is a lot of potential for further exploration and development.

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