Dynamics of innovation in makerspaces and fabrication labs: a systematic literature review

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Dynamics of innovation in makerspaces and fabrication labs: a systematic literature review

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Abstract

Makerspaces and fabrication laboratories (fablabs) have received extensive attention recently due to their potential to drive innovation and entrepreneurship. These spaces provide access to high-tech tools to the people and encourage community building and collaborations around technology-oriented projects. This paper analyzes the existing research on the innovation dynamics within these spaces. Seventy peer-reviewed studies were selected and thematically analyzed from the Scopus and Web of Science databases. The results are analyzed and presented as descriptive statistics and thematic analysis. We found nine significant themes from the extant literature: 1) Collaborations, learning and sharing practices in makerspaces; 2) Motivations and spatial environment affecting makerspace innovations; 3) Physical Resources, experimentations, and knowledge dimension of makerspaces; 4) Diversity and inclusion aspects of makerspaces; 5) Social and economic impact of innovation in makerspaces; 6) Regional innovation policies and maker cultures; 7) Maker movement in different regions; 8) Maker movement and the city culture; and 9) Academic makerspaces and innovation. The paper contributes to the broader literature on innovation dynamics within informal spaces like makerspaces and fablabs.

Keywords: makerspaces, fabrication laboratories, fab labs, creative open spaces, innovation, systematic literature review, thematic analysis

JEL Codes: O30; O32

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1. Introduction

Makerspaces and fabrication laboratories (fablabs) have received extensive attention recently due to their potential to drive innovation and entrepreneurship. The increase in makerspaces worldwide has been touted as the next big thing, a so-called maker movement (Hatch, 2014) or the next industrial revolution (Anderson, 2012). Makerspaces are known by different names, the most common being fablabs, hackerspaces, and hobby shops (Farritor, 2017). These spaces are often community-driven and promote grassroots digital fabrication by providing a physical infrastructure for the public to build, create, learn, and collaborate on different projects and experiments (Smith et al., 2013).

Halbinger (2018) defines them as open-access communities where people can interact and use collaborative knowledge and skills to build and create new projects. The author further elaborates that these spaces give the public access to modern, high-tech tools that are otherwise difficult for lay people to access. Hence, in typical makerspaces, one can access modern, sophisticated technologies like 3D printers, CNC cutters, laser cutters, microelectronic stations, and traditional tools like hammers, saws, and sewing machines (Beltagui et al., 2021; Smith, 2017). Beltagui et al. (2021) write that the people using such spaces are called makers who work independently to create technological innovations without the resources or directions of commercial organizations.

A significant level of collaboration, knowledge sharing, and social exchange among the makers from different backgrounds, an increased focus on the creation of knowledge and skill sharing and the development of technological innovations using advanced technologies which were previously inaccessible to the public are some of the features that distinguish makerspaces and fablabs from other innovation spaces (Browder et al., 2019). For these reasons, policymakers and urban planners became quite interested in them, driven by a conviction that they could support local manufacturing (Vinodrai et al., 2021). The way makerspaces and fablabs open avenues for new communities in technology development is also seen as a grassroots innovation movement (Smith, 2017; Smith et al., 2017).

Though makerspaces started as independent, community-driven, open-access spaces with modern tools and technologies for the public, they were soon adopted by academic institutions, corporate houses, and even healthcare settings. In educational institutions, makerspaces were started to complement the theoretical training of students, particularly in the engineering domain, with hands-on applications in design-focused projects (Wilczynski, 2015). Similarly, companies use makerspaces to invite employees and external actors like customers and suppliers to collaborate on innovative projects to increase the innovation impact of the enterprises (Rieken et al., 2020). Many healthcare settings, like hospitals, medicine, and nursing departments, use such spaces to allow healthcare users and providers to implement their ideas (Marshall & McGrew, 2017; Svensson & Hartmann, 2018). Such diverse uses and applications of makerspaces have increased interest in studying their contribution and impact on teaching curriculum and pedagogy and supporting user innovations.

The adoption of the makerspaces, which started as a grassroots movement to democratize the tools and technologies to the masses (Smith, 2017), by companies, educational institutions, and even urban/public policy agendas led to its diverse governance form. Fu (2021), for instance, describes two types of governance models for the makerspaces in the existing literature. The first is a "commons-based peer production bottom-up model," which is based on openness, decentralized, community-owned, not-for-profit makerspace, whereas the other is a "public policy based top-down model," which is a hierarchical, for-profit, entrepreneurial makerspace (Fu, 2021). Thus, the potential that the makerspaces present led to an increase in establishing such spaces, especially in the advanced economies of the global north. Different agendas and motivations fuel this rise and can be seen in conjunction with the interest from the governing bodies in integrating these facilities into the broader policies and initiatives through funding, events, and urban transformation projects (Diaz et al., 2021; Ferretti & Van Lente, 2022).

Despite the proliferation of literature on makerspaces and fablabs, it remains highly fragmented, with limited efforts to synthesize this body of knowledge. For instance, the studies by Soomro et al. (2022, 2023) review how makerspaces and fablabs have impacted and supported creativity. Similarly, Mersand (2021) overviews the literature on makerspaces, fablabs, and making. The potential of makerspaces on digital empowerment (Smolarczyk & Kröner, 2021) and how these networks can contribute to the global south's development (Seo-Zindy & Heeks, 2017) have also been a topic of review. A few review papers have focused on the role of makerspaces in educational settings such as libraries and K12 educational environments (Kim et al., 2022; Konstantinou et al., 2021; Papavlasopoulou et al., 2017; Schad & Jones, 2020). Corporate makerspaces, issues of inclusivity in makerspaces, the role of makerspaces in early childhood, and bibliometric analysis of published literature on makerspaces have also been the focus of review (Chen & Wu, 2017; Hielscher & Smith, 2017; Johnston et al., 2022; Rieken et al., 2020; Sharma, 2021).

While these reviews have enhanced our understanding of makerspaces and their role in augmenting the creativity of individuals, none of them has exclusively focused on the innovation dynamics within such spaces. Overall, the current reviews neglect the factors affecting innovations in makerspaces and fablabs, such as motivation, learning, collaboration, and knowledge sharing. This gap in the existing research serves as a rationale for studying the innovation dynamics within makerspaces. Therefore, this paper seeks to achieve the following research questions:

- RQ1: How does the existing literature evaluate and analyze the role of makerspaces and fablabs in facilitating the generation of technological innovations?
- RQ2: What themes emerge by synthesizing existing research findings on the role of makerspaces and fablabs in facilitating technological innovations?
- RQ3: What gaps and avenues for future research can be identified from the review of the existing literature?

We conducted a systematic literature review of 70 research articles to answer these research questions. The remainder of the paper is structured as follows: Section 2 presents our methodology for this review. Section 3 provides a descriptive analysis of the selected papers. In Section 4, we conduct a thematic analysis of retrieved papers to review various themes addressed in existing studies on the role of makerspaces in generating technological innovations. In Section 5, we briefly discuss the findings of our review. Section 6 presents a research agenda that provides directions for future research in this area. The final section concludes by discussing our study's contributions and limitations.

2. Methodology

To answer the research questions, the study uses a systematic literature review (SLR) to identify and analyze the relevant studies on innovation dynamics within the makerspaces. An SLR is defined as a review "*that adhere closely to a set of scientific methods that explicitly aim to limit systematic error (bias), mainly by attempting to identify, appraise and synthesize all relevant studies (of whatever design) in order to answer a particular question (or set of questions)*" (Petticrew & Roberts, 2008). According to Tranfield et al. (2003), SLRs differ from traditional reviews as they follow a replicable, scientific, and transparent process. As per the authors, such a process involves an exhaustive search of literature while providing an audit trail of the reviewer's decision, procedures, and conclusions. We follow the three main steps for conducting a literature review: planning, executing the review, and reporting and disseminating (Tranfield et al., 2003). Fig. 1 illustrates the process we adopted in the paper detailing the procedure followed in each stage. The three steps are described in detail in the following sections.

Planning the review

The planning stage of the review involves selecting the appropriate database(s) and the right keywords for searching the literature. We chose both Scopus and Web of Science databases for this paper. Scopus, developed by Elsevier, and Web of Science, which Thomson Scientific developed, are two widely used scientific databases covering many journals (Falagas et al., 2008). The keywords identified for the search were based on past reviews and seminal articles published on makerspaces. Table 1 lists the search string used to retrieve the articles from Scopus and Web of Science. We also applied inclusion/exclusion criteria to find the relevant studies. Table 2 details the criteria for literature selection we adopted for this paper. The search was conducted in January 2023. We selected only peer-reviewed articles written in English from the social science, business management, and economics disciplines. Since we were interested in the process and dynamics of innovations within makerspaces, we excluded fields like engineering, medicine, and allied disciplines. Using this process, 576 articles were retrieved (328 from Scopus and 248 from Web of Science).

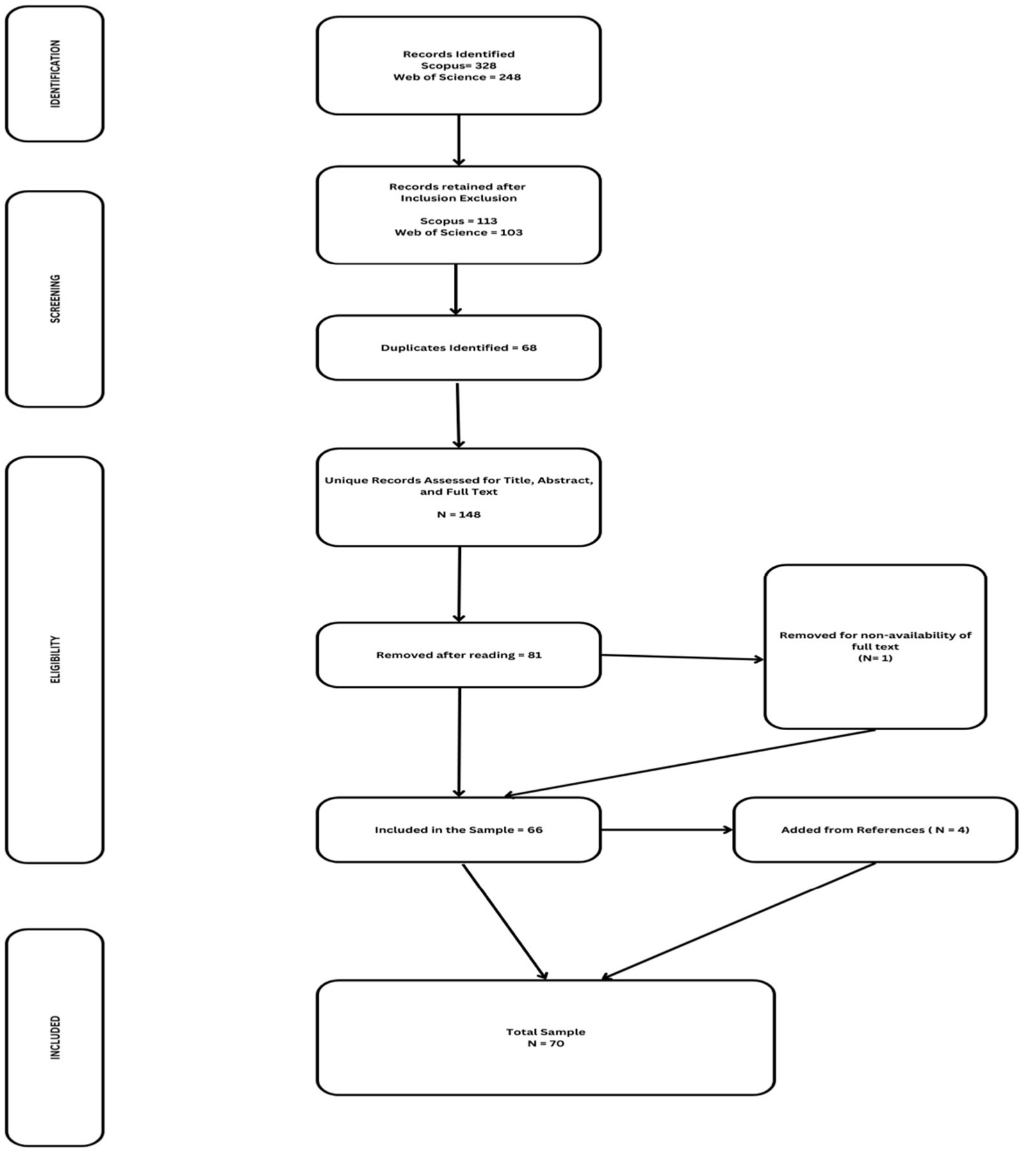

Figure 1: Methodology flow

Table 1: Search string for retrieving articles

Database	Search String
Scopus	(TITLE-ABS-KEY ("makerspace*" OR "fab lab*" OR "fabrication lab*" OR "fabrication laboratory*" OR "hackerspace*" OR "hack lab*") AND TITLE-ABS-KEY (innovation*)) AND PUBYEAR < 2023 AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (SUBJAREA , "SOCI") OR LIMIT-TO (SUBJAREA , "BUSI") OR LIMIT-TO (SUBJAREA , "ECON")) AND (LIMIT-TO (LANGUAGE , "English"))
Web of Science	"makerspace*" OR "fab lab*" OR "fabrication lab*" OR "fabrication laboratory*" OR "hackerspace*" OR "hack lab*" (Topic) and innovation* (Topic)

Table 2: Inclusion and exclusion criterion

Criteria	Included	Excluded
Document Type	Research Articles	All other documents, like review articles, conference papers, book chapters, and Editorials
Subject area	Social Science, Economics, Business Studies and Management	Engineering, Natural Science, Applied Science etc
Language	English	Non-English
Cut-off date	Articles published before 23 January 2023	All articles indexed/published after 23 January 2023

Screening the review

This step involves checking for duplicates and manually going through each article to make sure they are relevant to the answer to our research questions. After applying the inclusion and exclusion criteria, 216 articles were eligible for the study. We used MS Excel's duplicate data look-up feature to identify and remove 68 research articles. The remaining 148 unique papers were manually read in four stages: title, keywords, abstract, and full paper. This eligibility assessment technique is recommended and used in various review articles (Sharma & Dahlstrand, 2023; Haldar et al., 2023; Hansen et al., 2015; Salim et al., 2018). As per these authors, the first step involves carefully examining the title to determine its relevance for the study. If there is a lack of information in the title, the keywords are analyzed. If both keywords and title fail to give an idea about the paper's relevance, we moved to read the abstract and the full text to exclude all the irrelevant articles. These criteria ensured that our selected sample included articles focused on the nature or dynamics of innovations within makerspaces. Therefore, articles that discussed the role of makerspaces and fab labs for educational purpose or their role in pedagogy and teaching curriculum were not considered for the review and were removed from the final sample. Following this assessment criteria, 81 unsuitable research articles were removed, while one paper was removed due to its unavailability. We also reviewed the paper's references to ensure we didn't miss any paper not included due to not being one of the databases chosen for the study. As a result, we added four more papers to the sample.

Analysis

The analysis is done in two parts. In the first part, descriptive statistics are presented. Section 3 presents the findings of this analysis. The descriptive trends are complemented using a thematic analysis of the selected papers. For this, we followed Braun & Clarke's (2012) steps to identify themes and sub-themes by carefully examining the full text of 70 research articles and coding each paper according to its thematic focus. Next, we grouped similar codes to create nine main themes, detailed in Table 3. These major themes were reviewed and re-examined. Any differences related to codes and themes between the authors were deliberated until we reached a consensus. After reaching an agreement, we appropriately named all nine themes. Section 4 analyses these nine themes and the primary research papers within each theme.

3. Descriptive results

3.1 Distribution of articles by year

Due to the topic's novelty, we did not put any time limit while retrieving papers in this area. The articles in our sample covered ten years, from 2014 to 2022[4]. The data shows a significant increase in the topic from 3 paper in 2014 to 14 in 2022 (Fig. 3). There was a sharp increase from 2018, with six articles, to a peak in 2020 and 2021, with 14 articles each year. This was followed by a slight decrease to 10 in 2022. Nevertheless, the distribution reflects a growing interest in makerspaces from the social science, management, and economics community. The decline post-2020 could be due to covid, which might have impacted empirical studies on makerspaces.

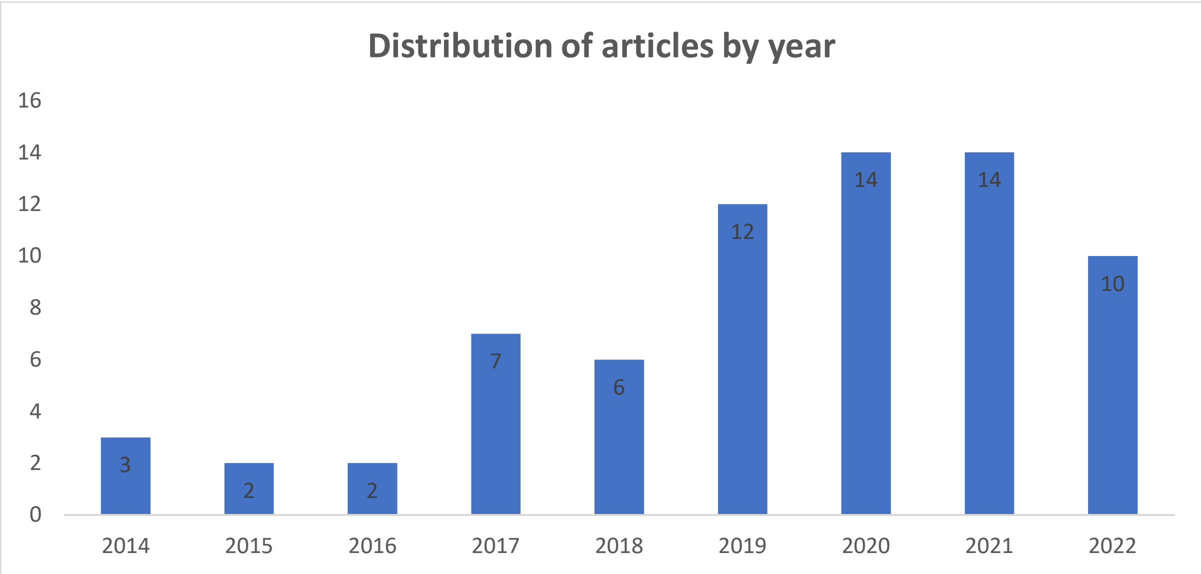

Figure 2: Distribution of articles by year

3.2 Distribution of journals

The papers have been published in a wide variety of journals. However, as Table 3 indicates, Technology in Society and R&D Management have been the most popular journals in the area, with three papers each. Eleven journals have at least two publications in this area, while 42 journals have published at least one paper on the innovation dynamics within makerspaces.

[4] Certain articles were published online and indexed on Scopus in one year but received their volume and issue numbers in the following year. For clarity, our distribution is based on the year indicated in the journal's official article information, not the initial online publication or Scopus indexing year.

This variety in journal selection indicates that the topic is a popular area of focus for academics from different disciplinary backgrounds.

Table 3: Journal distribution for the articles

Journal	**Number of articles**
Technology in Society	3
R&D Management	3
Creativity and Innovation Management	2
Sustainability	2
Research Policy	2
The Journal of Technology Transfer	2
Science Technology and Human Values	2
Advances in Engineering Education	2
Technological Forecasting and Social Change	2
Journal of Enabling Technologies	2
Telematics and Informatics	2
Journal of Manufacturing Technology Management	2
Journal of Business Research	2
42 Journals with one publication	1

3.3 Regional distribution of the articles

Table 4 lists the regions where the studies on innovation dynamics of makerspaces have been conducted. The results indicate that most studies were done in Europe (27 articles), followed by Asia (15). Among the 27 studies done in Europe, four have been done in Germany and the UK, three in France, two in Italy, and one in Portugal, Turkey, Sweden, Spain, and Scotland. Nine studies in the European region have been multi-country, i.e., with data from more than one nation. Among the 15 articles from Asia, eleven have been conducted in China and one in the Philippines, Taiwan, India, and Korea. A total of 12 articles are either transcontinental studies or written from a global perspective. North American makerspaces have contributed nine articles, with eight from the USA and one from Canada. Africa, South America, and Australia have been the focus of four, two, and one articles, respectively. Among African nations, two studies have been conducted in South Africa, one in Ethiopia, and one has been a multi-country study. Similarly, one study has been done in Brazil and Chile from the two articles from South America.

Table 4: Geographical distribution of papers

Geographic region	**Number of articles**
Europe	27
Asia	15
Global	12
North America	9
Africa	4
South America	2
Australia	1
Total	**70**

3.4 Methodological approaches

Regarding the methodological approach followed by the articles, we see that around 63% of the articles (n=44) have used a qualitative approach. The dominant method among qualitative papers is case studies of makerspaces using semi-structured interviews and secondary data. 17% of the articles have used quantitative methods (n=12), and surveys and econometric analysis are the methods for data analysis. Seven papers have used mixed methods for studying innovations within the makerspaces, while seven articles are conceptual. Figure 4 displays the methodological approach adopted in the studies.

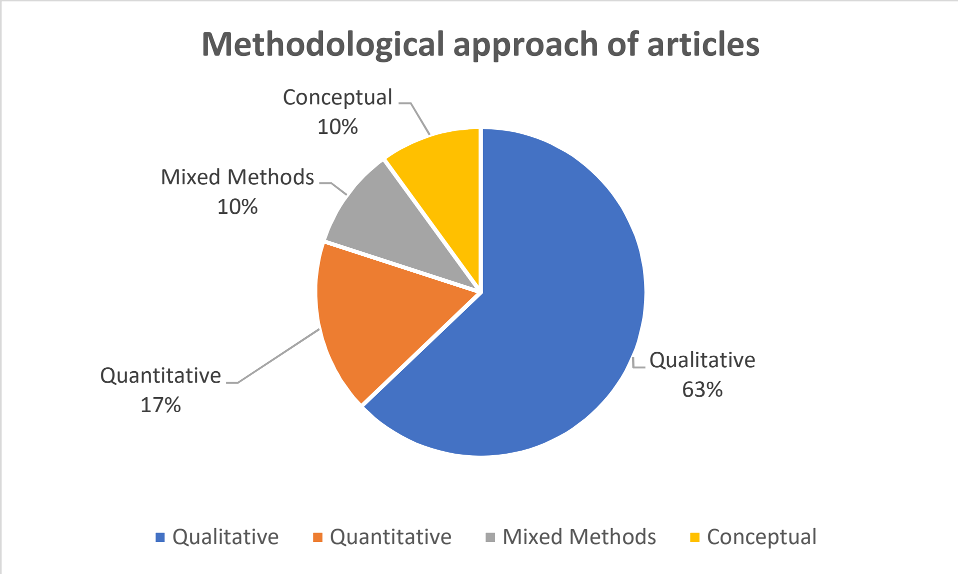

Fig 4: Methodological approach in the articles

4. Thematic analysis

In this section, we analyze the studies based on emerging themes. We identify nine thematic areas around which the research on innovation dynamics in makerspaces has been conducted. We discuss each of these themes in the following subsections. Some papers categorized under one theme may intersect with others. However, to highlight the primary objective, we allocate each to a single theme. Table 5 summarizes each of the nine themes and their corresponding references from the sample.

Table 5: Thematic distribution of the literature

Theme	Main arguments	References
Collaborations, learning, and sharing practices in makerspaces	Collaborative learning Community building Innovation commons Peer-to-peer networking	(Aryan et al., 2021; Cohendet et al., 2021; Johns & Hall, 2020; Kera, 2014; Leminen et al., 2021; Lhoste, 2020; Mortara & Parisot, 2016; Oswald & Zhao, 2021; Schmidt & Brinks, 2017; Suire, 2019; Tabarés & Kuittinen, 2020)
Motivations and spatial environment affecting makerspace innovations	Personal empowerment Intrinsic motivation	(Davies, 2018; Gantert et al., 2022; Han et al., 2017; Huang et al.,

	Economic and social motivation Capability enhancement Individual creativity	2021; Li & Gao, 2021; Donovan & Smith, 2020; Yang et al., 2022)
Physical Resources, experimentations, and knowledge dimension of makerspaces	Digital technologies Citizen science Living labs Entrepreneurial experimentation Shared fabrication facilities	(Beltagui et al., 2021; Browder et al., 2019; Gascó, 2017; Halbinger, 2018; Kruger & Steyn, 2020; Lô & Diochon, 2020; Maravilhas & Martins, 2019; Schneider & Lösch, 2019; Smith, 2017)
Diversity and inclusion aspects of makerspaces	Causes of inclusion Women centered spaces People with disabilities	(Bosse & Pelka, 2020; Masters et al., 2019; Rosner & Fox, 2016; Vinodrai et al., 2021; Hellwig et al., 2022; Lo & Diochon, 2019)
Social and economic impact of innovation in makerspaces	Regional economic outcomes Social innovation Environmental impact University's third mission Covid related impact	(Hicks & Faulk, 2018; Kieslinger et al., 2021; Kruger & Steyn, 2022; Rayna & Striukova, 2019; Richterich, 2020; Svensson & Hartmann, 2018; Unterfrauner et al., 2019; Valenzuela-Zubiaur et al., 2021)
Regional innovation policies and maker cultures	Regional innovation system Policy perspectives National innovation policies	(Bolli, 2020; Cattabriga, 2019; Fuet al., 2021; Fu, et al., 2022; Lindtner, 2014; Zhao & Zou, 2021)
Maker movement in different regions	European and North American makerspaces Asian makerspaces African makerspaces Latin American makerspaces	(Rejeb & Roussel, 2022; Carqueijó et al., 2022; Corsini, 2022; Li, 2022; ElHoussamy & Rizk, 2020; Fu, 2021; Haldar & Sharma, 2022; Lindtner, 2015; Manzo & Ramella, 2015; Martins & Albagli, 2020; Parlak & Baycan, 2020; Ramella & Manzo, 2018; Santos et al., 2018)
Maker movement and the city culture	City's development Citizen engagement in issues Regional entrepreneurial growth	(Besson, 2021; Budge, 2019; Lin, 2019; Niaros et al., 2017; Schmidt, 2019; van Holm, 2017)
Academic makerspaces and innovation	Engineering and design curriculum Digital humanities Library makerspaces	(Forest et al., 2014; Halbinger, 2020; Leebaw & Tomlinson, 2020; Nichols et al., 2017)

4.1 *Collaborations, learning, and sharing practices in makerspaces*

Collaborations, learning, and sharing are at the core of makerspaces, as they allow the members to work together, share ideas, and learn from each other. Papers in this theme explore these facets of makerspaces and fablabs and how they enable individuals to create and innovate. As makerspaces can be found independently and within institutional settings like libraries, Leminen et al. (2021) provide distinct typologies for such spaces. They call them the low-contextual innovation model and the high-contextual innovation model. As per these authors, in the low-contextual innovation settings, the users are also involved, but their role is limited, while in the high-contextual innovation settings, users have an active role in the co-creation, development, and validation of ideas. Makerspaces within libraries are included in the former model, whereas fablabs are included in the latter.

Similarly, concerning collaborative learning, Oswald & Zhao (2021) explains that collaborative learning, along with self-learning and formal learning, helps individuals and groups in their knowledge development. They argue that collaborative learning in makerspaces boosts the members' technical skills and helps them move towards high-complexity learning areas. The management of the makerspaces and community interaction within them affects collaborative learning.

The concept of a community within the spaces has received attention from scholars and how they influence innovation. The study by Schmidt & Brinks (2017) points out four distinct types of 'creative labs' attractive to different communities: experimentation labs, working labs, open innovation labs, and investor-driven labs. Users from diverse backgrounds with varying collaboration goals use these types of labs. For instance, the authors write that experimentation labs are more attractive to hobbyists, whereas working labs are conducive to business and working professions. In contrast, open innovation labs are spaces offered by science and technology-based companies and institutions to outsiders to absorb and build on their knowledge, while investor-driven labs focus more on supporting the startups in their commercial journey (Schmidt & Brinks, 2017). The type of structure, support, and resources available in these settings also influence collaboration and community building as people often move from one setting to another. For instance, Mortara & Parisot (2016) mention that community-owned spaces are less expensive than other options, but evidence suggests that they may not be well-equipped or well-maintained. Thus, people keep transitioning from one type of setting to another to gather the different collaborative support structures they offer.

The collaborations and the knowledge creation process within makerspaces have also been explained within the discourse of 'innovation commons' (Cohendet et al., 2021). The authors describe the innovation commons as enabling the community to build common institutional arrangements and governance structures to support collaborations and sharing of the ideas and resources within, which makes these spaces open to all, network-oriented, and having a minimum set of tools and technologies. However, such collaborations do not seem attractive to actors outside the community. As noted in the study by Tabarés & Kuittinen (2020), the present structure of openness, collaborations, and peer-to-peer networking makes the makerspaces appealing only to the makers and not actors such as manufacturers. Thus, to make innovation more societally relevant and economically beneficial, they advise promoting maker activities to other actors and establishing shared spaces to facilitate collaborations. Suire (2019) analyses makerspaces interactions with the firms in the city where fablabs are based. Their study finds that frequent interactions of the fablabs with small firms positively influence the production of exploratory projects. In contrast, interactions with large firms increase spin-off productions and decrease experimental projects.

The papers on this theme also discuss the potential of involving civil society and the issues arising in such a context (Kera, 2014; Lhoste, 2020). Lhoste (2020) argues that though DIY labs offer an opportunity for opening to the knowledge of the common people, they require intermediation. As civil society brings its world views and lay knowledge, the absorption and facilitation of their expertise need a critical role to be played by the managers of fablabs and makerspaces as they can coordinate the activities, facilitate engagement, and contribute to the technical and social knowledge. Similarly, in the context of DiYBio, Kera (2014) writes that such a movement has allowed the engagement of the knowledgeable public in scientific and technological production. The involvement of citizens in science projects has allowed for the experimentation with facts, norms, values, and testing ideas.

Makerspaces, fablabs, and other such spaces which allow for a building up of community are also places where the 'peer production' process takes place. Aryan et al. (2021) describe them as a collaborative platform for informal yet organized peer-to-peer cooperation and exchange that enables alternative innovation pathways and knowledge flows. Nevertheless, the culture of sharing and collaboration, celebrated in the literature and popular discourse on makerspaces, has been found contradictory with practice. For instance, in the study of Fab Lab in Manchester, Johns & Hall (2020) take a critical look at the notion of sharing in makerspaces and fablabs. The authors argue that the reality of sharing is antithetical to what is romanticized as individualistic norms and ideas emerge here that limit the practice of sharing. Time and financial constraints, as well as the commercial orientations of the members, reduce their collaborative associations in these places.

4.2 *Motivations and spatial environment affecting makerspace innovations*

In studies on makerspaces and fablabs, another aspect that has garnered significant attention from researchers is the motivations and the external factors that influence people to use these spaces for their innovative projects and other creative pursuits. Davies (2018), in the study on the culture of *hacking* in the makerspaces in the US, finds that people engage more in leisurely activity and develop new skills. As per their study, these spaces provide them with personal empowerment, entertainment, and self-actualization opportunities. The author finds that for people, these spaces provide them access to people with a similar mindset, which they refer to as 'tribe' and 'family.' Hence, personal benefits rather than political ones are observed as drivers to engage in makerspace projects (Davies, 2018). The study by Han et al. (2017) highlights the importance of makerspace environmental support in fulfilling users' basic psychological needs and increasing intrinsic motivation, ultimately leading to continued usage. The authors find that economic support had the most influence in makerspaces, satisfying users' autonomy and competence needs. In contrast, technical support was positively associated with autonomy but had no effect on competence, and social support had a significant impact on relatedness but did not fulfill the competence requirement (Han et al., 2017).

Studies have also explored the role of motivations of the makers to engage in innovative pursuits. The study by Yang et al. (2022), for instance, explores the role of different motivations in the innovative behavior of makers. They find that economic motivation has a positive effect on exploitative innovation and a negative impact on exploratory innovation, while social motivation positively affects exploratory innovation and negatively affects exploitative innovation. The study also examines the impact of makerspace environments, specifically the innovation climate, on makers' innovation behavior. Their results indicate that a strong climate for innovation can enhance social motivations' positive influence and diminish economic motivation's negative influence on exploratory innovation (Yang et al., 2022).

The study by Li & Gao (2021) investigates how makers' innovation performance is affected by their relationship networks and knowledge acquisition. Their findings suggest that strong and weak ties positively affect makers' innovation performance, with strong ties having a slightly stronger impact. Moreover, knowledge acquisition partially mediates between the makers' relationship network and innovation performance. Li & Gao further suggest that makers establish and maintain their relationship networks, participate in maker events, and utilize online communication tools to improve their innovation performance. In the context of the UK, the study by Donovan & Smith (2020) studied how makerspaces offer their users enhanced capabilities. They find that the range of capabilities in UK makerspaces is not as extensive as claimed for makerspaces in general. They highlight how expanding capabilities for individuals within the same or similar makerspaces depends on wider structures.

Similarly, the study by Gantert et al. (2022) identifies key factors contributing to innovativeness in makerspaces, including moral foundations, social responsibility, team size, user experience, and access to technical facilities. Their research shows no necessary condition for user innovativeness in makerspaces, and that specific recipe configurations can enhance innovativeness. In another study, Huang et al. (2021) examined the influence of workspace environments on employee behavior and innovation performance within makerspace in China, uncovering the significant impact of physical environments on individual and team behaviors and the importance of fostering communication and collaboration through well-designed workspaces. While their study acknowledged the role of individual creativity in innovation, it stressed the vital importance of team cooperation and the necessity for organizational heads to enhance innovative environments by addressing physical and non-physical aspects.

4.3 *Physical Resources, experimentations, and knowledge dimension of makerspaces*

Makerspaces or similar spaces have attained an important place in the discourse on innovation, primarily due to their ability to offer resources that are typically inaccessible to the average person. These include digital tools like 3D printers and other fabrication tools that assist in prototyping. Studies on this theme focus on the different resources available in makerspaces, making innovative projects easy to pursue. Beltagui et al. (2021) explore the use of 3D printing technology in makerspaces and how it contributes to democratizing innovations. The authors write that makerspaces offer free or low-cost access to fabrication tools, like 3D printers, that enhance traditional manufacturing and promote bricolage and synergy within their communities, empowering citizens to innovate sustainably, but 3D printing role as an enabler of bricolage should not be overemphasized. Digital fabrication tools have especially become synonymous with spaces like makerspaces and fablabs. Schneider & Lösch (2019) argue that fablabs and open-source 3D printing have become closely linked. The driving principles of fablabs stem from the aspiration to decentralize, democratize, and make innovation processes more accessible as essential technical equipment, such as 3D printers and drones, play a crucial role in characterizing fablabs and envisioning their possibilities (Schneider & Lösch, 2019). Thus, fablabs are now seen as gateways into a future where digital fabrication is universally accessible.

Gascó (2017) investigates the role of living labs as public open innovation intermediaries, specifically studying Citilab and the fab athenaeum network. The author writes that while both initiatives can be considered living labs, real-world experimentation remains underdeveloped. The innovation processes in these labs primarily aim to enhance citizens' quality of life and contribute to social innovation. Therefore, to increase impact and sustainability, living labs must attract more users and stakeholders and develop their experimentation capabilities. The importance of makerspaces and fablabs in the wider context of the entrepreneurial ecosystem is also argued. For instance, Kruger and Steyn (2020) emphasize the significance of innovation spaces in fostering technology transfer and innovation within entrepreneurial ecosystems. The authors discuss that these spaces encourage collaboration and market needs identification and provide guidance on research, networking, and investment. Therefore, leveraging these spaces can stimulate indigenous development via SMEs, enhance research commercialization, simplify patenting processes, and enable diversified offerings such as spin-offs (Kruger & Steyn, 2020).

Studies on this theme have also focused on the role of makerspaces in fostering experimentation and creativity, both in independent hackerspaces and within structured companies like Renault's Creative Lab (CL). In the context of a hackerspace based in Scotland, Smith (2017) observes how the whole atmosphere of the lab is focused on experimentation and imagination. The author discusses the participants' hacking techniques for developing complex patterns and dealing with the challenges of making robots. Their study also emphasizes the emergent and unexpectedness of experimentation. It is not only the independent makerspaces or fablabs which foster such types of collective working and creativity. The study by Lô & Diochon (2020) examines the development of contextual ambidexterity within the highly structured company Renault, focusing on the Creative Lab (CL) 's role. As per the authors, the CL fosters contextual ambidexterity by enabling employees to bypass traditional innovation processes and encouraging exploratory activities through rapid prototyping and improvisation tools. Their study also identifies an alternative source of contextual ambidexterity outside business units based on autonomous initiatives and bootlegging behaviors.

Knowledge sharing and experience of the members also play a crucial role in the process of innovations within makerspaces. Knowledge is created through the socialization, externalization, combination, and internalization of explicit and tacit knowledge (Maravilhas & Martins, 2019). Thus, these authors suggest that fablabs managers should value and manage knowledge as a resource, both internal and external, to increase the successful projects of the Lab. In a similar view, Browder et al. (2019) emphasize that the maker movement's defining characteristic lies in the knowledge dimension, which influences outcomes. Central to the movement, as per these authors, are knowledge creation and sharing spaces, transcending organizational boundaries, and fostering innovative knowledge development. These spaces comprise virtual and physical environments, such as online platforms and shared fabrication facilities, and events such as Maker Faires offer networking opportunities for makers at various levels, from local to international (Browder et al., 2019).

In addition to the knowledge dimension, studies also highlight the potential of these spaces in fostering innovation and diffusion. For instance, Halbinger (2018) reveals that makerspace participants exhibit higher innovation and diffusion rates than household sector innovators, as makerspaces lower costs and provide resources, tools, and knowledge. As per Halbinger's study, makerspaces could foster innovation and venturing activities crucial for technological, societal, and economic progress. Therefore, the author recommends designing policies to support makerspaces while considering members' interests and incumbent firms' resistance.

4.4 *Diversity and inclusion aspects of makerspaces*

The diversity and inclusion aspect of makerspaces has received considerable attention from scholars. Studies in this dimension have focused on how such spaces provide a platform for people from different social groups to leverage technology for their purpose. Despite the popularity of makerspaces over the years, they have faced several challenges and criticism regarding the diversity, equity, and inclusion aspects of the users of these spaces. For instance, Vinodrai et al. (2021) highlight the challenges faced by makerspaces in maintaining diversity amongst the members and promoting environmentally conscious practices due to funding, staff capacity, and community engagement limitations. Their study finds that predominantly memberships, expensive fees, and material costs often become reasons for excluding people from different groups. In the same way, they also highlight staff and budget constraints as reasons for the lack of sustainability promotions.

However, some makerspaces have tried to address these issues by creating exclusive spaces, such as HackerMoms, which challenges traditional hacking concepts and promotes inclusion and growth, as Rosner & Fox (2016) discussed. These authors study a hackerspace operated and used only by mothers, allowing them to collaborate, learn, and express themselves creatively. They write that such an exclusive space challenges conventional and masculinized hacking concepts, leading to the establishment of other women-centered and feminist hackerspaces. However, their article also discusses two types of failures experienced by this mother-operated space: productive self-defined failure and failure imposed by outsiders. Productive self-defined failure involves shared vulnerability and growth, while imposed failure comes from criticism of the group's focus on women (Rosner & Fox, 2016).

Studies also discuss the potential benefits and challenges of engaging people with special needs and from differently-abled groups to make makerspaces more inclusive. Hellwig et al. (2022) investigate individualized product development involving makers and people with disabilities. They find that such spaces promote collaborations, faster implementation of ideas, and user-centeredness, leading to the development of more individualized assisted devices. The potential benefits offered by such collaborations include valuable input during the idea phase, a shortened iteration cycle, and cost-effective assistive products. However, the authors also point out the challenges, such as the complexity of manufacturing technologies and communication among the diverse team members. Involving groups from diverse needs nurtures diversity and inclusivity in the innovation process in the makerspaces. Masters et al. (2019) address the difficulty of establishing inclusive makerspaces and the need to adopt context-specific and adaptive methods for ensuring diversity among the makerspaces. Bosse & Pelka (2020) also highlight how makerspace can empower people with disabilities to participate in product development actively. Their study also highlights makerspace resources like 3D printers for helping makers with disabilities develop affordable assistive tools and foster social innovation.

Makerspaces based in corporate settings can also be a space for the empowerment of company employees. Using the case of Renault's Fab lab, Lô & Diochon (2019) argue that such third spaces promote informal activities and provide an environment for employees to act freely as they challenge the organization's existing culture and propose a new order.

4.5 *Social and economic impact of innovation in makerspaces*

This strand of literature explores the economic, social, and environmental impact of innovations developed in makerspaces. The studies provide mixed results as some question the efficacy of these spaces in terms of economic impact, while others emphasize the social value of the innovations developed in makerspaces. Hicks & Faulk (2018) in their paper do not find any evidence to suggest that makerspaces and other similar sites improve regional economic outcomes. They further write that public spending on such sites could potentially divert public resources from crucial sectors like infrastructure, public safety, or education, which may substantially influence the regional economy. In the context of makerspaces in Swedish public hospitals, Svensson & Hartmann (2018) writes that such spaces enable the development of valuable innovations with potential returns exceeding the investment required to establish and operate them. Therefore, innovations originating from makerspaces hold substantial value, offsetting the non-development and partial development of ideas that may have remained unexplored in their absence.

The location of the makerspace plays a role in determining its sustainability in terms of cost and revenue. Rayna & Striukova (2019) categorize makerspaces into three types in terms of their location: educational, industry, and residential. Though the aspects of the social innovation process remain consistent across all three types, educational makerspaces operate under low-cost/low-revenue conditions, industry makerspaces in high-cost/high-revenue settings, and residential makerspaces face the most challenging high-cost/low-revenue circumstances (Rayna & Striukova, 2019). The environmental impact of makerspaces is also studied as a dimension of their sustainability. Unterfrauner et al. (2019) highlight the potential for positive outcomes through repairing, recycling, and upcycling and the Maker movement's role in shifting from consumerism to *prosumerism* and decentralized local production. However, their study acknowledges ongoing challenges, such as supply chain transparency, sustainable resource management, environmental awareness, and concerns like 3D printer filament recycling and home-based digital fabrication impacts. In the context of a fablab based in a university, Valenzuela-Zubiaur et al. (2021) find that the spaces promote social innovation and enhance the university's third mission by fostering interdisciplinary collaboration and leveraging digital technology, facilitating partnerships with entrepreneurs to address social needs, develop commercial products, and support the Quadruple/Quintuple Helix model, ultimately contributing to sustainability through increased cooperation among ecosystem participants.

The impact of innovative activities of makerspaces during the pandemic has been studied and analyzed. These studies explore the crucial roles makerspaces played during the COVID-19 pandemic, examining their contributions to addressing PPE and medical device shortages and their impact on innovation environments and open-source technology. Kieslinger et al. (2021) studied five makerspaces across three continents that addressed the COVID-19 pandemic to highlight the potential for makerspaces to address societal challenges and contribute to systemic change in the future. Similarly, Kruger & Steyn (2022) explored the use of technologies like additive manufacturing (AM) by makerspaces during covid-19. The case study revealed that, under certain conditions, a makerspace has the potential to promote innovation, facilitating the early adoption of AM in developing nations. This effectiveness of AM as a flexible production technology is amplified within a broader innovation ecosystem. Richterich (2020) writes that these initiatives relied on open-source designs and collaboration.

Therefore, examining these practices through the lens of critical making unveils their societal importance and ramifications for open-source technology as the maker communities demonstrated adaptability and promptness as emergency responders, emphasizing the promise of open-source design in healthcare innovation (Richterich, 2020).

4.6 *Regional innovation policies and maker cultures*

Studies on this theme explore the effect of regional innovation systems and policies on complementing and supporting the existing maker cultures in a different region. While most of the studies on this theme emerge from China, it shows how the maker culture has become a part of public policy to support innovations. Zhao & Zou (2021) highlight the regional innovation system around Hangzhou, which has helped shape the maker culture of Dream Town. The authors write that closeness to universities and research institutes and a solid regional industrial structure has helped to shape an ideal environment for the makerspaces providing industrial resources, networks, and an entrepreneurial atmosphere. Similarly, Bolli (2020) explores the transformation of maker culture in urban environments and the influence of China's urban landscape on promoting innovation. The authors write that cities such as Shanghai and Shenzhen have emerged as hotbeds for experimentation due to top-down governmental strategies converging with grassroots creativity. Makerspaces have been instrumental in China's transition from a manufacturing hub to a center for innovation.

Lindtner (2014) highlights China's unique maker culture, rooted in its existing hardware repair workshops and factories and driven by necessity rather than countercultural ideals, as seen in Western practices. Shenzhen, as per the study, a critical region for hardware startups, embraces openness in manufacturing, which has fostered innovation and creativity. Shanzhai production has evolved from counterfeit products to an open manufacturing system that shares hardware design schematics and materials lists. In contrast, Cattabriga (2019) emphasizes the development of the Regional Innovation System (RIS) and makerspaces in the Emilia-Romagna region of northern Italy, where the Mak-ER network promotes a maker culture. This network strengthens relationships and serves as an interface between various sectors, with local authorities supporting it through promotion, coordination, and economic assistance (Cattabriga, 2019).

As research transitions from urban maker culture to a broader policy perspective, it highlights the significant role of China's Mass Innovation and Mass Entrepreneurship initiative in nurturing innovation. The government significantly promotes innovation through the Mass Innovation and Mass Entrepreneurship policy, which emphasizes entrepreneurial solutionism and addresses the nation's developmental challenges by targeting specific groups, such as college students, migrant workers, and veterans (Fu et al., 2021). Also, Chinese Mass Innovation Spaces (MISs) differentiate themselves from global makerspaces by supporting entrepreneurs and startups, connecting them to capital and markets, and offering coworking spaces, investments, and resource connections instead of making tools (Fu et al., 2021).

4.7 *Maker movement in different regions*

Studies on this theme explore the maker movement's characteristics, drivers, and comparative features in different parts of the world. These studies reveal the maker movement's unique manifestations, regional nuances, and the factors that led to its growth and emergence in different parts of the world. Some studies on this theme have explored how places like fablabs and makerspaces are operationalized and governed, while some studies compare the maker movement with other regions. In a study comparing the Italian fablabs with its counterparts based in other European cities and the US, Santos et al. (2018) find that Italian fablabs mostly rely on volunteers and serve individual customers, while fablabs in other regions are inclined towards training and research. The use of digital technologies is prevalent in these regions as they believe in its revolutionary role that can impact various aspects of the industry (Santos et al., 2018). Similar findings are observed by Carqueijó et al. (2022), studying the Portuguese fablabs where the making is more catered towards individual customers, digital manufacturing, with laser cutting machines and CNC machines being the most used equipment.

The strong manufacturing traditions of the regions have also played a role in cultivating the maker movement. For instance, in Italy, Manzo & Ramella (2015) write that the widespread nature of fablabs can be attributed to the country's manufacturing status. However, they observe less public support; hence, compared to France, the maker movement relies more on voluntarism (Ramella & Manzo, 2018). In contrast, the government of France has been noted to support and encourage the growth of fablabs in the country. In the context of the transcontinental nation of Turkey, Parlak & Baycan (2020) study the creative hubs in the region that have been established by individuals who have experienced similar needs or have been part of these communities themselves. The primary motivations for building a making culture in Turkey include fostering project generation, enabling new collaborations, adapting to shifting work conditions, and tackling urban challenges through local participation and decision-making (Parlak & Baycan, 2020).

The maker culture and its rise have also been studied in the context of Asia. However, China has been the focus because of the policy push from the government to support these spaces. Lindtner (2015) writes that the country's *shanzhai* history influenced the movement in China— an informal network of producers, traders, and design houses sharing production-ready designs— featuring replicating branded devices and repurposing discarded phones. Thus, one can find a slightly different style of governance and institutionalization of makerspaces in China. Such makerspaces in China, as per Fu (2021), do not follow either the commons-based peer production model of Europe or the strict top-down public policy model; instead, they are a "subtle top-down model" that mixes government and non-government actors in the functioning. Therefore, the government's involvement as a promoter and partner has made them more widespread in the region and a reason for China's shift from an industrial-based economy to a service economy (Fu, 2021).

Among other Asian nations, the Philippines and Indian maker movements have also been studied. Li (2022) studies the outcomes from the spaces in the Philippines, which can be divided into three broad types: 1) research-based projects and STEM elite culture, 2) commercial-oriented projects, and 3) creative and grassroots projects. As per the author, such variations are due to the governance styles or how external communities, makerspaces, and their users interact with others. In the Indian context, the makerspaces in the city of Bengaluru have been the topic of study. Makerspaces in Bengaluru are found to be multifaceted and informally linked to formal institutions. They attract diverse members and have mixed motives, such as profit-making and social value creation, and also provide decentralized, bottom-up, localized manufacturing alternatives to traditional industrial production models (Haldar & Sharma, 2022).

The maker culture of African makerspaces has been studied in the extant literature. For instance, how an African makerspace gains, maintains, and defends its legitimacy has been the focus of a study (Corsini, 2022) in the context of Ethiopia. The study finds that for the Ethiopian makerspace, it is crucial to obtain support from relevant stakeholders, establish a credible reputation, cooperate with established makerspaces, concentrate on achieving initial successes, foster the exchange of resources between partners from the Global North and South, and adopt best practices and quality assurance measures to establish and preserve legitimacy. In the context of Egyptian, Moroccan, and Tunisian makerspaces ElHoussamy & Rizk (2020) observes that maker culture in these regions tends to provide peer-to-peer collaboration, customized internship programs, and technical workshops for learning and innovation. They also provide skill building, diplomas, and certificate courses for the makers on design and manufacturing. Makerspaces in these three regions, as per the authors, promote creativity in developing affordable solutions to address local challenges and demands. There may be occasional conflicts regarding innovation ownership; makerspaces prioritize open collaboration over formal intellectual property protection. Rejeb & Roussel (2022), using lexicometric analysis, study an Ethiopian fablab FabLabENIT's position concerning four factors: use and purpose, impact, structure and organization, and field of application. They find that although the organization is highly correlated with the third factor (structure and organization), it could improve its position on the other fronts to enhance its position; the article recommends several actions, such as adopting process-oriented activities and techniques, enhancing visibility through improved communication, and clarifying the scope of its field of application (Rejeb & Rousel, 2022).

Finally, in the context of Latin America, the sole study in the sample by Martins & Albagli (2020) explores how the movement in Brazil was shaped by the initiatives such as the MetaReciclagem network and the Living Culture Program, which encouraged cooperative production, open-source technology, and unconventional licenses. The movement also drew from the activities of digital culture activists in Brazil who were involved in the Living Culture Program.

4.8 *Maker movement and the city culture*

Studies in theme highlight how maker movement influences a city's culture and can potentially stimulate urban practices and local economic development significantly. Makerspaces or the 'open creative labs' are mainly located in urban agglomerations, particularly in gentrified areas with a high concentration of creative professionals and entrepreneurs serving as intermediaries facilitating connections between local and trans-local communities while serving the local needs (Schmidt, 2019). Makerspaces contribute to economic development by fostering cultural change, bolstering small business growth, providing informal workforce training, enhancing workforce retention, promoting entrepreneurship, offering office space and specialty tool access, and imparting tool usage skills, especially for younger individuals (van Holm, 2017).

Such spaces are also vehicles for a citizen-led transformation in community building, learning, and innovation. As citizen-driven transformation institutions and physical nodes of collaborative culture, makerspaces democratize production means through a commons-oriented approach, allowing people to engage in technology development and experimentation within a community-driven, collaborative environment (Niaros et al., 2017). Makerspaces enrich the urban regions with the dynamism required for thriving cities, and citizens increasingly engage in making activities attracted by the community, learning, and work-related opportunities (Budge, 2019).

Makerspaces also referred to as 'third places,' embed digital technologies in cities and revitalized them by creating a locale of experimentation and interaction by bringing various actors together (Besson, 2021). The citizens use the tools and resources of these third spaces to address the specific socio-economic, cultural, urban, and environmental challenges they face. Lin (2019) writes that makerspaces practice alternative worldling practices through socio-spatial strategies regarding craft and technology-oriented products. The authors also highlight the local socio-economic development and the global subculture that influence the strategy makerspaces adopt for the relationship with the state.

4.9 *Academic makerspaces and innovations*

Makerspaces have also become popular within academic institutions as they provide faculty and students with various tools and a platform to design, experiment, and develop projects.

They also tend to bridge the theoretical and practical knowledge gap, especially in engineering and design science. Studies in theme explore the working and contributions of makerspaces to the overall culture of innovation and entrepreneurship in academic institutions. Forest et al. (2014), studying a university makerspace Invention Studio, write that such a space enables students to work on self-identified projects that help improve engineering identity, deepen understanding of engineering fundamentals, and improve retention. Thus, a makerspace such as Invention Studio provides a valuable resource for engineering education as it showcases the value of hands-on design-build education for innovation, creativity, and entrepreneurship.

The benefit of an academic makerspace is not only for the technical courses or disciplines. Their usefulness for fields such as humanities is also noted. For instance, Nichols et al. (2017) highlight the importance of academic makerspaces in supporting digital humanities by citing examples from of iSpace at the University of Arizona. As per their study, the space promotes collaboration between students, faculty, and library staff, leading to skill acquisition and cross-disciplinary learning. However, for such successful makerspace projects, it is essential to build potential partnerships with colleges and other campuses to support transdisciplinary efforts (Nichols et al., 2017). Academic libraries have also shown considerable interest in setting up and managing makerspaces to support innovation and being a platform for collaboration (Leebaw & Tomlinson, 2020). However, more research is needed on this theme to measure the impact of makerspaces on innovation and creativity in academic institutions. It is crucial to investigate the role of makerspaces in promoting innovation and entrepreneurship, explore the factors that enhance creativity and gamification in the entrepreneurial process, and examine the possibility of integrating makerspaces into the curricula of universities focused on developing entrepreneurial ecosystems (Halbinger, 2020).

5. Discussion

The above themes shed light on the innovation dynamics of makerspaces in different national, subnational, and sectoral contexts. Creating open spaces emerged with a vision to promote community participation in innovative activities, to deliberate, ideate, and co-create solutions for everyday problems, or simply to engage in learning and skill development, accessing the freely available digital and modern tools. However, the role and utility of makerspaces have evolved owing to the growing need to transform students from typical consumers of technology, skills, and ideas to embedding them as active participants in creative innovation. Especially in the STEM subjects, the recent economic and job market changes mandate greater skill and training in modern technology and communication, as well as soft skills like collaborative thinking and working, compared to the 1980s. This has resulted in a spurt in makerspaces, fablabs, etc., within educational institutions and corporate houses. They are becoming extremely vital in bridging the STEM learning gap by opening spaces for creative learning and hands-on experiences (Wilczynski, 2015; Rieken et al., 2019). The growing scholarship on understanding the impact of makerspaces on the innovation potential of pedagogy and teaching environments is an attempt to capture this phenomenon.

The increasing consensus on the usefulness of makerspaces in promoting an entrepreneurial culture and citizen-driven innovation has led to the emergence of different forms of governance models based on the agenda and audiences of a particular makerspace. In addition to the 'commons-based peer production model,' which is mostly a bottom-up, community-owned, not-for-profit, open space for innovation and co-creation, recent years have witnessed a growth in a top-down 'public policy-based governance model' that aims to integrate the agenda of citizen-driven, open innovation in national and subnational policy (Fu, 2021). Such governance frames identify makerspaces as levers for more people-centric and entrepreneurship-driven economic regeneration and urban transformation (Diaz et al., 2021; Ferretti & Van Lente, 2002).

The general trends in makerspaces literature focusing on innovation dynamics reveal increasing interest among researchers from diverse disciplines, including science and technology studies, management, business studies, sustainability, and policy studies, especially in the recent half a decade (2017 to 2022). However, given that the number of articles hosted by each journal, as per the sample of this review, doesn't exceed three articles, with 42 journals only publishing 1 article each in this area, it reveals fragmentation and lack of focus on innovation dimensions of makerspace in the extant literature. Looking at the geographical and methodological trends, most literature emerges from Europe, followed by Asia, but mainly focused on China. Makerspaces are critical in democratizing innovation for collaborative problem-solving related to climate change and sustainable agriculture. They provide opportunities for entrepreneurship and support local value chains, particularly in developing economies where small businesses and the informal sectors face significant resource constraints. Hence, this presents a need to explore how maker culture can be created by tapping into different finance streams and introducing regulatory intervention to support innovation and entrepreneurship through such open spaces. Methodologically, the qualitative case study method dominates makerspace and innovation dynamics research. Only 10 percent of the papers in this sample contribute to expanding the conceptual understanding of how makerspaces can be leveraged to create an ecosystem of entrepreneurship and innovation.

Moreover, there is a need to move away from analyzing only a few micro cases of makerspaces to draw conclusions. If the culture of innovation is to be promoted through makerspaces, fablabs, and similar spaces, they should be brought to the forefront of economic development. This way, they can offer collaborative, context-specific solutions to the rapid global urbanization. In that case, looking into these innovative spaces' finance and investment side is necessary. Researchers should investigate how broader industrial, economic, and urban policy can support the development of such spaces by theorizing and providing empirical support with larger data sets while experimenting with different governance structures and business models.

Regarding how makerspaces and fablabs enable people to collaborate, co-create, learn, and share, studies have categorized these spaces into distinct typologies - low contextual innovation (e.g., libraries) and high-contextual innovation (e.g., fablabs) model. These typologies are based on the level of active participation of users in creating and validating ideas (Leminen et al., 2021). Similar studies emphasize the role of collaborative learning in improving people's skills to bolster them towards high-complexity learning areas (Oswald & Zhao, 2021). Making makerspaces as collaborative learning arenas depends on the users' goals and background/contexts. Based on diverse collaboration goals and the type of structure, support, and resource access in various makerspaces, they can be categorized as experimentation, open innovation, working, and investor-driven labs. The possibility and evidence of people moving from one setting to another exemplify the underlying potential and flexibility for skill development (from low skill to complex problem solving) based on changing goals and aspirations of communities (Schmidt & Brinks, 2017).

Studies focusing on the collaborative aspects of makerspaces critique the current 'innovation commons' based approach. This approach involves common community-led institutional arrangements, peer-to-peer networking, and access to a specific set of tools and technologies deemed most useful to maker communities. Such closed maker-centric arrangements make these spaces less lucrative to outside actors, such as manufacturers and diverse communities (Tabares & Kuittuinen, 2020). Opening makerspaces to various sectors has social and economical regenerative effects, as frequent interactions of these spaces with small and large firms support experimentation in small firms and spin-off productions in larger firms (Surie, 2019). The role of civil society actors as intermediaries that help disseminate the knowledge produced in makerspaces to common people while bringing in world views and lived experiences in the innovation process is crucial (Lhoste, 2020). Financial and time constraints and commercial orientations are major setbacks to the collaborative spirit of makerspaces and fablabs (Johns & Hall, 2020).

The development and sustenance of makerspaces and fablabs in varied contexts depend on users' motivations and spatial factors. For instance, in the US, people engage with makerspaces as they offer opportunities for leisure, personal empowerment, self-actualization, and new skill development (Davies, 2017). In addition to intrinsic personal motives, extrinsic factors such as economic support, technology access, and training define citizen engagement in makerspace projects (Han et al., 2017). Different types of motivations define the form of innovation the users engage in (e.g., exploratory innovation for social causes, exploitative innovation for profit motives). Focusing on the burgeoning culture of innovation in China, studies argue that physical environments significantly impact innovation performance and team behavior (Huang et al., 2021). Thus, creating conducive ecosystems for financing, knowledge sharing, and technology transfer through industrial policy, along with fostering communication and co-creation through well-managed and designed makerspaces at the firm level, are crucial drivers of innovation culture.

Studies on understanding the knowledge dimension of maker movements argue that makerspaces are not just physical spaces. They are also conceptualized as virtual online platforms that offer networking and knowledge-sharing opportunities to diverse actors (Browder et al., 2019). Thus, policy support for innovation should consider people's motivations and socioeconomic contexts to allow for different configurations of these creative spaces regarding ownership models, structure (physical/virtual/ formal/ informal, etc.), and financing arrangements. Although at the heart of making is the idea of democratizing innovations by center-staging the principle of inclusive development, recent literature points out that expensive membership fees, material costs, inadequate staff capacity, and limited community engagement exclude different actor groups from makerspaces (Vinodrai et al., 2021). As a counterargument to this, certain makerspaces are created as exclusive spaces for often marginalized groups such as women, differently abled, etc. By offering a platform for individualized product development, these spaces help collaborations with specific actors with specific problem sets and promote faster implementation, testing, and validation of innovations. This automatically translates to cost-effective, user-centered products with shorter iteration cycles.

From an innovation policy perspective, the role of non-commercial institutions such as universities and research institutes, in addition to a stable and rigorous regional industrial structure, enables the convergence of top-down government strategies with bottom-up grassroots creativity. For instance, China's regional innovation and industrial policy bolstered the making culture by making industrial networks, resources, and technologies available to small-scale manufacturing units, hence fostering an ecosystem for entrepreneurship and innovation (Fu et al., 2022; Bolli et al., 2020). This supports our argument that small-scale solutionism through fragmented innovation spaces is insufficient. It would not effectively and inclusively resolve economic, environmental, and social development challenges at a national or subnational level. Hence, the state's role should be to develop a mass culture of innovation and entrepreneurship by supporting the manufacturing sector, startups, and informal businesses. This can be achieved by embedding them in capital and goods markets and offering them access to coworking spaces and knowledge and material supply chains rather than providing them with making tools (Fu et al., 2022). There is no set configuration of how a makerspace should be governed and institutionalized. The maker movement has manifested uniquely depending on regional and national socio-political, technological, and economic contexts. For instance, regions with historically strong manufacturing traditions, like Italy, France, and China, have a bustling culture of makerspaces. Moreover, structural changes like China's shift from an industrial to a service-oriented economy have steered its national and subnational policies towards an innovation-centric approach.

On the other hand, the maker movement in Latin America was mainly carried on the shoulders of digital culture activists (Martins & Albagli, 2020). Thus, the dynamics of innovation in makerspaces are place-based and complex and unfold in multiple contexts of governance, industry, academia, and urban sectors. To say that makerspaces can serve as enablers of industrial regeneration and economic development is not a misguided notion, as evident in examples from China, France, and Italy.

6. Conclusion

The review systematically analyzed how the innovation dynamics within makerspaces and similar spaces like fablabs have been addressed in the published literature. We used a systematic literature review method to achieve the objectives and divided our results into descriptive statistics and thematic analysis. The general trend on the topic reveals a growing interest in this area from 2019 with a slight decline from 2020, possibly due to COVID-19's effect on the physical working of many such places. A renewed interest in the topic is expected again as many nations worldwide have started to include makerspace development in their public and urban policy agendas. The current understanding of the innovation dynamics of makerspaces is limited because of literature primarily from the European region and papers adopting qualitative methodologies. More studies employing quantitative or mixed methodology are needed regarding methodological diversity. Similarly, more geographic diversity is needed by studying the phenomenon in the context of Asian (except China), Latin

American, and African countries. These places' cultural and contextual specificities and their effect on innovative practices in makerspaces will enhance the understanding of this topic.

The paper makes several contributions to the broader literature on innovations and makerspaces. The review contributes to the extant literature on innovation studies by synthesizing the innovation dynamics of informal spaces like makerspaces and fablabs. As the literature on this topic is scattered and distributed across journals from various disciplines, the review will be useful for researchers and policymakers working in this area. Although several reviews on makerspaces exist, they do not exclusively focus on the innovation dynamics within them. This paper identifies the various themes of these innovation dynamics within such spaces that further the understating of both innovations and the role of spaces like makerspaces.

The systematic review adopted also has its limitations due to the choices made in the selection of databases and the inclusion/exclusion criteria: 1) the choice of databases and search methods may have led to the exclusion of relevant articles and grey literature; 2) manual data handling could have caused some concepts to be overlooked; and 3) the use of thematic analysis may have allowed for researcher bias. Future research in this area can address these limitations using the systematic review method.

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