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Artículos científicos

Laboratorios de Fabricación Digital (FabLab) y su implementación en educación básica. Una revisión sistemática

Digital Fabrication Laboratories (FabLab) and its implementation in basic education. A systematic review

Laboratórios de Fabricação Digital (FabLab) e sua implementação na educação básica. Uma revisão sistemática

Isaac Antonio Jarillo Aguilar
Universidad Rosario Castellanos, México
211pde21@rcastellanos.cdmx.gob.mx
https://orcid.org/0000-0003-0044-0877

Resumen

La revisión de literatura realizada en el presente estudio ofrece un panorama acerca de los Laboratorios de Fabricación Digital (FabLab) y cómo se han implementado en escuelas de educación inicial. El objetivo ha sido conocer qué se ha publicado sobre fabricación digital y educación básica durante los últimos 10 años en bases de datos especializadas. La metodología que se ha seguido implica los siguientes pasos: 1) Definición de los criterios de búsqueda, 2) Ejecución de la búsqueda y 3) Discusión de los resultados.

Para ello, se realizó una búsqueda documental en las bases de datos SCOPUS y Web of Science, aplicando un filtro para mostrar únicamente los artículos publicados entre los años 2012 y 2022. Como resultado, se han encontrado seis artículos que abordan temáticas al respecto, cinco de ellos fueron publicados en Europa y uno en Estados Unidos. De los cinco artículos europeos, solo uno de ellos fue publicado en un país de habla hispana, en este caso, España.

Los artículos coinciden en que hay aportes significativos al implementar FabLab en escuelas de educación básica, tales como desarrollar la creatividad e innovación de las alumnas y alumnos, enseñarles cómo producir sus propios objetos y productos, fomentar el trabajo en equipo y la colaboración. De igual manera, la mayor parte de estos estudios mencionan que la información obtenida es un punto de partida para futuros proyectos que involucren acercar a las niñas y niños a la fabricación digital.

Palabras Clave: Fabricación digital, educación básica, revisión sistemática

Abstract

The literature review realized on this research offers a perspective about Digital Fabrication Laboratories (FabLab) and how they have been implemented at basic schools. The objective has been to know what has been published about digital fabrication and basic education though the last 10 years on specialized databases. The methodology that has been applied followed the next steps 1) Definition of the research criteria, 2) Search execution and 3) Results discussion. For that, it has been done documental research at SCOPUS and Web of Science databases applying a filter to show only articles that have been published between 2012 and 2022. As a result, it was found six articles about these topics, five of them were published at Europe and one at United States. From the five European articles, just one of them was published on a Spanish-speaking country, Spain.

The articles agree there are meaningful contributions when implementing FabLab at basic education schools, such as develop students' creativity and innovation, it teaches them how to produce their own objects and products, teamwork, and collaboration. As well, most of these investigations indicate obtained information is a starting point to future projects that involve approaching girls and boys to digital fabrication.

Keywords: Digital Fabrication, basic education, systematic review.

Resumo

A revisão da literatura realizada neste estudo oferece uma visão geral sobre os Laboratórios de Fabricação Digital (FabLab) e como eles têm sido implementados nas escolas de educação infantil. O objetivo foi conhecer o que foi publicado sobre manufatura digital e educação básica nos últimos 10 anos em bases de dados especializadas. A metodologia seguida implica os seguintes passos: 1) Definição dos critérios de pesquisa, 2) Execução da pesquisa e 3) Discussão dos resultados.

Para isso, foi realizada uma busca documental nas bases de dados SCOPUS e Web of Science, aplicando um filtro para mostrar apenas os artigos publicados entre os anos de 2012 e 2022. Como resultado, foram encontrados seis artigos que abordam temas nesse sentido, cinco deles foram publicados na Europa e um nos Estados Unidos. Dos cinco artigos europeus, apenas um deles foi publicado em um país de língua espanhola, neste caso, a Espanha.

Os artigos concordam que há contribuições significativas ao implementar o FabLab nas escolas de educação básica, como desenvolver a criatividade e inovação dos alunos, ensiná-los a produzir seus próprios objetos e produtos, promover o trabalho em equipe e a colaboração. Da mesma forma, a maioria desses estudos menciona que as informações obtidas são um ponto de partida para projetos futuros que envolvam aproximar meninas e meninos da fabricação digital.

Palavras-chave: Manufatura digital, educação básica, revisão sistemática.

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Introduction

The STEAM (Science, Technology, Engineering, Arts and Mathematics) educational approach can significantly influence educational practice. It is important to take into account that the professional environment that students will face in the future involves professions that do not yet exist; therefore, updating the ways to bring students closer to knowledge should be an educational goal (Husted et al., 2020).

Within this ecosystem, one of the most complex projects are the Digital Fabrication Laboratories; however, its implementation generally occurs at Higher Education and Graduate levels. Therefore, integrating a similar space at basic education levels implies venturing into little-explored terrain.

The intellectual roots of FabLabs lie in the work of Seymour Papert and his collaborators at the Massachusetts Institute of Technology (MIT) Media Lab, who were pioneers in the field of educational technologies. Papert's constructionist perspective – the belief that children learn most effectively when they build models and share them with their peers – is at the heart of the Digital Fabrication Labs programs (Blikstein et al., 2019). .

The FabLab concept was conceived in the early 2000s at the MIT Media Lab by Neil Gershenfeld (in collaboration with Bakhtiar Mikhak) as a creative space for college students (Blikstein et al., 2019). However, in the following five years it has been successfully replicated in community and entrepreneurship centers.

According to The Fab Foundation (2022), a FabLab is defined as a space to play, create, learn, teach and invent. Usually, such a laboratory includes the following components:

- A laser cutter that creates 2D and 3D structures
- A 3D printer
- A CNC mill that can machine circuit boards, precision parts, and casting molds.
- A CNC router to build furniture.
- A set of low-cost electronic components and programming tools, plus high-speed microcontrollers and circuits for prototyping.

García Ruíz and Lena Acebo (2019) point out that:

"FabLabs are a reality that presents new opportunities for users and consumers to become designers and creators of everyday objects. Despite the fact that it has undergone spectacular growth in recent years, the FabLab movement, partly due to its youth and to a certain distance from the academic circuits as it is more related to the Maker culture and the Open-Source movement, it has been little formally studied." (p.373)

The Maker culture involves the manufacture of any type of object. However, as Dougherty (2012) mentions, this process is highly mediated by new technologies and digital tools; it is usually given with computer controlled machines. On the other hand, the Open-Source movement implies that programmers can read, modify and redistribute the source code of a program, correcting its errors and adapting it to their needs (TecNM [Tecnológico Nacional de México], 2019).

Despite being a concept that is more than 20 years old, it is not easy to find studies carried out in Latin America that talk about FabLab in basic education levels in specialized databases. There is even less talk about situations such as gender equality within these spaces, their possible integration into marginalized communities, or the attention they could provide to vulnerable people. For this reason, a review of the existing literature in specialized search engines has been proposed.

Therefore, the objective of this exploration seeks to find out how many articles on education and digital fabrication have been published in the Scopus and Web of Science databases, in addition to finding out if any of them have been published in Latin America, addressing approaches to vulnerable communities. The hypothesis that directs this research dictates that, by knowing the panorama of digital fabrication in basic education, it will be possible to know what has been done, what are the strengths and areas of opportunity, in order to provide the interested public with a guideline, an overview that serves as a starting point for future research.

To guide this research, the following questions were posed:

1. How many articles in SCOPUS and WOS talk about Digital Fabrication Laboratories?
2. Have the studies carried out been carried out in Latin America?
3. Have these studies focused on vulnerable children's communities or specifically on girls?
4. What impact on education do these studies report?

Methodology

To answer the questions raised in this research, a systematic literature review has been chosen. This method is used to carry out a review of quantitative and qualitative aspects of primary studies, with the objective of summarizing the existing information regarding a particular topic. The researchers, after collecting the articles of interest, analyze them and compare the evidence they provide with that of other similar ones (Manterola et al., 2013, p. 149).

Štrukelj (2018) highlights that the importance of carrying out a systematic review of the literature lies in the fact that the results obtained can give rise to a certain level of credibility with respect to its conclusions, being also one of the best methods to summarize and synthesize the evidence on any specific research question.

The methodology proposed for this study has been based on the model proposed by Petersen et al. (2008), which involves the following steps:

1. Definition of search criteria, which include the research questions, the period of time, criteria to include or eliminate articles, and last but not least, the search string.
2. Execution of the search: launch the search in the selected databases, always under the search criteria established in the previous step.
3. Discussion of the results: in this stage the data obtained are analyzed, they are compared and presented to the reader.

Initially, this study set out to search SCOPUS and WOS for articles that addressed not only FabLab, but also gender equality. However, no results were obtained, the same thing happened when it was decided to combine FabLab and Women. By combining the keywords FabLab and Childhood (as well as related words such as Children and Childhood), only one result was obtained. Similarly, combining FabLab and Latin America also yielded a limited number of results, between two and four, in the Web of Science (WOS) database.

Due to the above, it was decided to combine the FabLab and Education keywords, since this combination yielded more results and thus it will be possible to have a study that provides more points of comparison. It is worth mentioning that each of these combinations was introduced in English, since it is the one used by the databases chosen for this exploration.

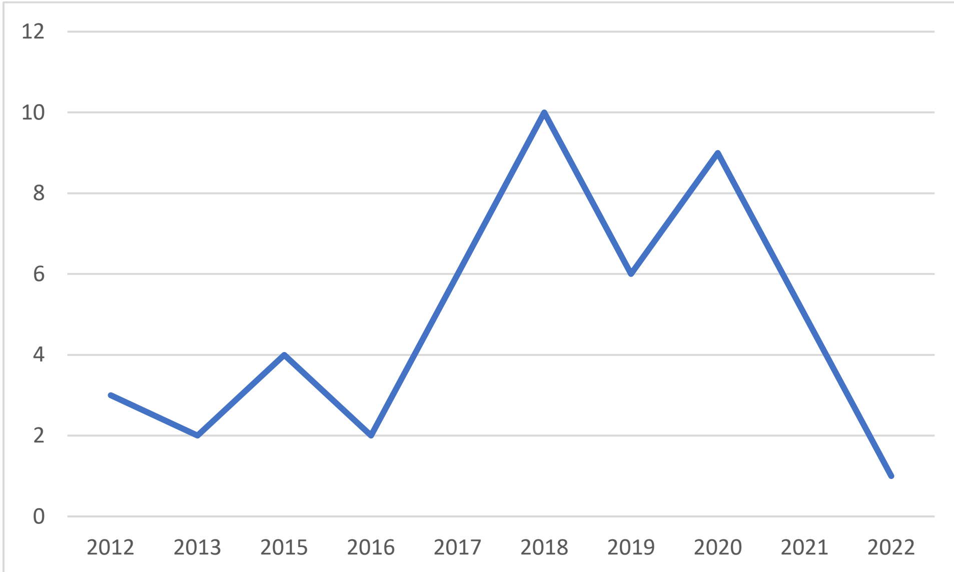
For this search, in addition to the keywords mentioned, the following filters were used:

a) Only consider articles.
b) Documents included in a period of ten years (2012-2022)

Once the search parameters were defined, we proceeded to search at SCOPUS and WOS databases using the following search string: (("FabLab") AND ("Education")).

The results obtained in SCOPUS were 34, while in WOS 50 were obtained. Of these 50 WOS results, two were discarded because they were duplicates of SCOPUS and six more that turned out to be book chapters, giving a total of 42 results. Next, the titles, keywords and abstracts were analyzed, and based on this, 6 articles from SCOPUS and 22 from WOS were eliminated, since they were not related to FabLabs or addressed cases of laboratories that were not implemented in environments educational. This resulted in a final total of 48 articles dealing with digital fabrication in educational settings, from basic to postgraduate level, including non-formal education settings as well.

Figure 1. Quantity of published articles by year



Source: Self-made.

In Figure 1, it can be seen the number of articles published during the established period of time. Of the selected articles, it is observed that from 2012 to 2016, the production of articles has been extremely low. However, in 2017, it begins to rise, and during 2018 the maximum production of articles related to the subject was reached, with a total of 10. Although in 2019 the figure decreases to 6, in 2020 it rises to 9 articles, despite being the year in which the COVID-19 pandemic began. However, in 2021, the figure decreases to 5, and during the first half of 2022, which is as far as this study covers, only one article on the subject has been published.

The peak reached in 2020 is the second highest. In this case, it is possible that the number of items may be due to the COVID-19 pandemic. Although the pandemic caused a crisis in the health system, it also brought with it other phenomena such as the increase in the number of academic publications. Callaway (2020) indicates that scientific publications can be fast and open when scientists so desire; additionally, in the time of the pandemic, the journals brought the manuscripts to formal publication in record time, with the help of researchers who quickly reviewed the drafts.

Table 1. Articles production by country

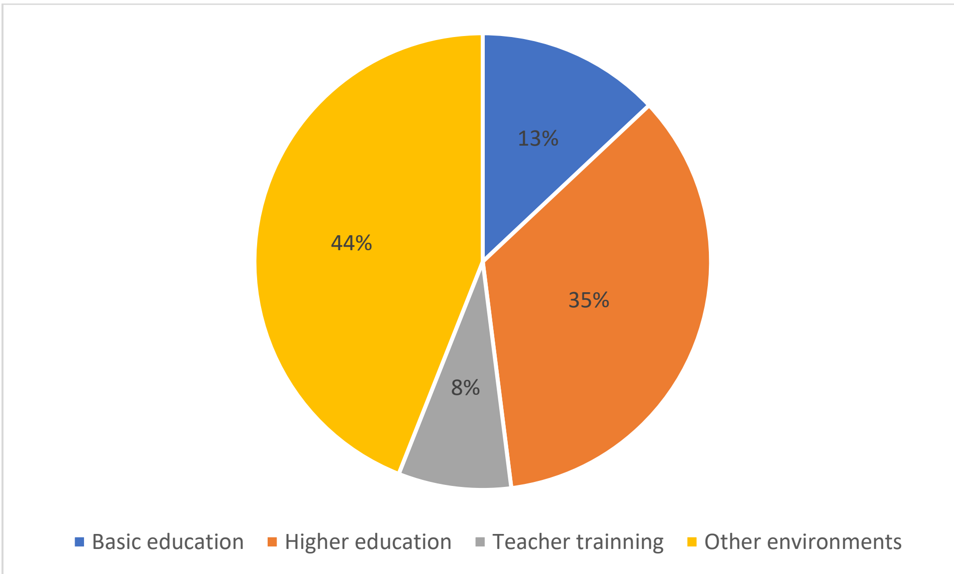
Country	Articles produced
USA	8
Italy	6
Spain	5
Belgium	3
Netherlands	3
UK	3
Germany	2
Brazil	2
Finland	2
Australia	1
Austria	1
Cambodia	1
Chile	1
Croatia	1
Denmark	1
United Arab Emirates	1
Russia	1
France	1
Israel	1
Lithuania	1
Mexico	1
Portugal	1
Czech Republic	1
Serbia	1
Sweden	1

Source. Self-Made.

Based on the information in Table 1, in terms of the countries where most of the articles have been published, the United States and Italy are in the first places, with 8 and 6 respectively. In Spanish-speaking countries, Spain has the highest production with 5 articles, followed by Chile and Mexico with one article each. Based on this same information, it is concluded that most of the investigations are carried out in the United States and Europe. Asia has a very low presence, like Oceania, while no African country has published research on the selected topic. It should be noted that the total number of countries is greater than the number of articles, since some of them were carried out in collaboration between institutions located in different countries.

Despite the fact that the articles mentioned above address educational issues, an additional filter has had to be carried out, since the proposed study proposed an exploration of Digital Fabrication and Basic Education. The number of articles that study the subject delimited above is 6. Regarding higher education environments, 17 articles were found. Regarding the training of teachers and laboratory managers, 4 articles were found. On the other hand, the remaining 21 articles talk about informal education environments, education for work, entrepreneurship, community development and mixed environments.

Figure 2. Articles percentage by educative area



Source: Self-made

As seen in Figure 2, the largest number of studies in school settings focuses on university institutions with 35%. On the other hand, research focused on basic education represents 13%, which shows a difference of 22%. In other words, for every 2.7 higher education articles there is only one basic education article.

Table 2. Articles that address digital fabrication themes on basic education

Year	Title	Authors	Country
2012	First steps in the FabLab: Experiences engaging children	Posch, I.; Fitzpatrick G.	Austria
2017	An Assessment Instrument of Technological Literacies in Makerspaces and FabLabs	Blikstein, P.; Kabayadondo, Z.; Martin A.; Fields D.	USA
2017	Child Participation in the Transformation of their Learning Spaces: Democratizing Creation through a Digital Fabrication Project in a FabLab	Gonzalez-Patiño, J.; Esteban-Guitart, M.; San Gregorio, S.	Spain
2018	Newton - Vision and Reality of Future Education	Hrad, J.; Zeman, T.; Sladek O.	Czech Republic
2018	On the importance of backstage activities for engaging children in a FabLab	Dreessen, K.; Schepers S.	Belgium
2020	Embedded assumptions in design and Making projects with children	Ventä-Olkkonen, L.; Kinnula, M.; Hartikainen, H.; Iivari N.	Finland

Source: Self-Made

Based on what is shown in Table 2, it can be seen that, of the six articles that address a situation in basic education, five of these were carried out in European environments, while one was focused on the United States. Regarding the European articles, only one of them was carried out in a Spanish-speaking country.

Posch and Fitzpatrick (2012) mention that, although FabLabs are gaining popularity around the world, there is little understanding of children's interactions with these spaces. In their article, they reflect on the experiences gained from having conducted five extracurricular workshops at the FabLab Vienna over a period of a year and a half with 50 children ranging in age from 10 to 14. They studied how the children's interactions were throughout the activities, which provided valuable information for future studies involving children with digital fabrication technologies.

Blickstein et al. (2017) highlight that, as the Maker movement is integrated from preschool to high school, students are developing new skills in exploration and manufacturing technologies. Therefore, they propose an iterative study to develop an instrument capable of evaluating this new technological literacy and present the results obtained after having implemented it in five schools in three countries.

González-Patiño et al. (2017) have worked on a study carried out with two groups of primary education, third and fourth grade, from a school in the city of Madrid. The project involved discovering and applying processes of participatory design and digital fabrication, with the intention of producing an object for some improvement in their school. The first session consisted of visiting the FabLab of Medialab-Prado Madrid. In addition to presenting the laboratory, the general issues of the project and its objectives were explained. The next phase consisted of helping the children to carry out the analysis of their own needs and desires, proposing solutions and, later, choosing one by consensus, since the available resources only allowed one object to be produced. They agreed to design and create the classroom tables and chairs. The next step consisted of producing, with the laser cutter, a scale cardboard model of a series of pieces of furniture that combined geometrically with the tables in the classroom and that helped to solve the identified needs.

In the last work session in the FabLab, the final prototype was manufactured with the milling machine using wooden boards. Next, an activity was carried out with the pieces in real size that served to confront the ideation and design work with the real possibilities of use.

Hrad et al. (2018) carry out an analysis of the Newton initiative in several European countries. Within it, they point out that FabLabs allow the public to access state-of-the-art technologies and produce all kinds of articles, motivating interested apprentices. However, the disadvantage is that they have high operating costs that, if they are not subsidized by some type of subsidy, fall on the users, a situation that is problematic for the students.

Dreessen and Schepers (2018) report a study with two specific cases called "Wa Make" and "Making Things". In the first, a series of workshops were carried out in a school context, experiencing what they called “school fun” with less complex activities. In the second case, the workshops were longer, starting from the interest of the children and focusing on more complex activities. They concluded in both cases that STEAM education is key to changing the future of education.

Ventä-Olkkonen et al. (2020) generated a study where they point out that previous literature has highlighted the importance of teaching girls and boys Maker and design skills to acquire valuable skills for the future. Similarly, in their article, they have identified differences between participatory and user-centered design with respect to the Maker philosophy. While the user-centered and participatory design philosophy understands the user's needs and empathizes with it, the Maker philosophy often starts with the idea of creating things for one's own needs. The study was carried out with three different grades in a school, revealing challenges among boys and girls to understand the design process and the conflicts between designing for oneself and designing for others.

Discussion

The 21st century has been accompanied by a new consideration of traditional academic and school forms, both from a pedagogical point of view and from a learning space and time. It is possible to consider that there is a repositioning of learning spaces, transforming traditional spaces into techno-creative spaces (Sanabria Zepeda et al., 2019), such as the Digital Fabrication Laboratories.

However, since the documentary search did not find other articles that have carried out a systematic review on FabLab and basic education schools, it is impossible to make a comparison with a previous reference. Therefore, the content of the present investigation can be taken as a starting point for future work in this area.

According to the articles cited above, it is a fact that FabLabs are transforming education in educational institutions that have this type of laboratory; However, having found only six articles that address topics on the interactions of students in digital fabrication environments shows that these environments have been little explored, and the results presented in this article are not conclusive. On the contrary, they should be taken as an invitation to continue exploring this field of knowledge.

Walter-Herrmann and Büching (2013) appeal that FabLab-based activities should be included in the school curriculum to encourage problem-based learning, creative hands-on activities, and the development of skills to document and communicate ideas and problems efficiently. .

Additionally, digital fabrication spaces encourage the development of 21st century skills, which will help them move through complex environments in the information age. Since being in a globally competitive system, students must develop, as they need, the appropriate skills for life and work (Scott, 2015).

Although the authors point out some potential benefits of digital fabrication spaces, it must also be established that there is no single path for their implementation in basic education schools. The possibilities vary between countries due, among other things, to educational budgets, plans and programs.

While hundreds of schools around the world have embraced the Maker philosophy, most of these are concentrated in affluent areas, suburban areas, and private schools. To make a real impact, these opportunities need to be present in all schools and not just in the most privileged ones (Blikstein & Worsley, 2016).

Herrera et al. (2021) mention that FabLabs are spaces conducive to the integration of women with an interest in STEAM areas, promoting opportunities in different areas of engineering and related disciplines.

It is important that digital fabrication spaces are present in all environments, and even more so in those that suffer from some type of vulnerability, since, by not having an approach to this type of space, their development opportunities are suffering limitations, which in the long term will translate into fewer possibilities of academic improvement and of not being able to access better jobs, just to mention a couple of aspects.

However, the implementation of this type of spaces is not an easy task. In order to carry out its implementation in educational centers, specific hardware and software must be available for the educational level for which they are intended, in addition to trained personnel for their use (Marrero Alberto, 2017).

However, what is not mentioned in most of the sources consulted is that, in order to integrate a digital fabrication space, the type of school and budget must be analyzed in a particular way. It is not the same situation in public schools as in private schools, and it equally influences whether they are in an urban, suburban or rural area. There are also significant differences if we talk about developed countries and countries with emerging economies; each of them will have different priorities and not in all cases the budgets allocated to education contemplate this type of laboratory.

Conclusions

Returning to the questions posed at the beginning of the investigation, it is possible to provide an answer to each of them. Even so, in some cases the answers may not be entirely conclusive and provide guidelines for revisiting these issues in future research.

Question I: As can be seen from the results obtained, the first study that observed the interaction of girls and boys in a digital fabrication environment was published in the city of Vienna in 2012. Over time, only another 5 articles are found in SCOPUS and WOS, which shows that, even after a decade has passed, articles referring to FabLab and basic education environments or children's communities are still scarce.

Question II: In Latin American contexts, no studies have been found that address issues related to FabLab and basic education; the only Spanish-speaking country that has published in this regard is Spain in 2017.

Question III: None of these studies mention having emphasized girls' interaction with these spaces, or their implementation in vulnerable communities. Which is not entirely surprising, taking into account that the articles found do not even cover a dozen. It will be interesting to review in the future if there are articles about it.

Question IV: The articles consulted report a change in the paradigms of girls and boys, noting that technological education has a positive impact on their environments. They have become aware of how they can become creators instead of consumers.

It can be concluded from the information collected that digital fabrication environments generate improvements in school environments. However, its little implementation in basic education could be due to the fact that highly specialized personnel are required.

Additionally, the staff must be able to master technological teaching and be an expert in infant-oriented pedagogical techniques, with which they feel not only initial curiosity, but also the ability to construct their knowledge in a tangible and meaningful way prolonged in time. Special care must also be taken so that FabLabs do not become spaces that serve only to copy designs.

Future lines of Research

It will be important to carry out studies in later years to verify if the number of FabLabs in basic education schools has grown, if studies are being carried out in Latin America in this regard and, if so, to determine if its implementation has been more difficult due to the conditions socioeconomic and political characteristics of the region, in addition to verifying that the impact they generate is as positive as it has been in other latitudes.

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