Journal of Business Research 94 (2019) 353–359

Contents lists available at ScienceDirect

Journal of Business Research

journal homepage: www.elsevier.com/locate/jbusres

Strategic knowledge management in a digital environment: Tacit and explicit knowledge in Fab Labs

Sérgio Maravilhas*, Joberto Martins

UNIFACS - Salvador University | Laureate International Universities, R. Dr. José Peroba - Costa Azul, Salvador, BA 40301-155, Brazil

ARTICLE INFO

Keywords:
Creativity
Digital fabrication
Fab Labs
Innovation
Knowledge management
Makerspaces

ABSTRACT

Fab Labs are places of learning through the exchange of knowledge among its members. They allow to leverage innovation using technological resources available in the space, stimulating the creativity of its participants and enabling the development of products and solutions based on personal projects from ideation, or the construction supported on knowledge developed by other elements collaboratively, enhancing the result. It'll be described how users learn with others in Fab Labs, which are laboratories of digital fabrication, serving as prototyping platforms of physical objects, with broad educational, social and economic advantages. Its users can leverage their imagination and develop sustainable, social, local, economic innovative solutions to solve real problems, supported by tacit and explicit knowledge transfer. Seven semi structured interviews were performed with the Fab Managers of one Portuguese Lab, one Spanish Lab, one French Lab, one Italian Lab, and three Brazilian Labs. Interesting findings characterized the researched environments.

1. Introduction

The importance of knowledge for organizations is now widely recognized, being one of the resources whose management influences the success of organizations (Davenport, 1997; Davenport & Prusak, 1998; Maravilhas, 2014).

Information and knowledge are a social and strategic tool for organization survival and success (Beuren, 1998; Choo, 1996, 2003; McGee & Prusak, 1995).

Fab Labs, Makerspaces, Hackerspaces, and Techshops are collaborative spaces for stimulating innovation, through the exchange and sharing of information, knowledge, and experience among its members (Blikstein, 2014; Troxler, 2014).

They leverage innovation using technological resources available in the space, stimulating the creativity of its participants and enabling the development of products and solutions based on personal projects from ideation, or the construction supported on knowledge developed by other Makers, collaboratively, enhancing the result (Gershenfeld, 2005, 2012).

With the motto “Learn, Make, Share”, these spaces aim to empower its members for the realization of sustainable solutions, local and community-based, using open source tools and equipment's whenever possible (open software, open hardware, open design, open learning), promoting open Innovation (Chesbrough, 2003) to allow all the possibility of creating low cost products, with the ability to very quickly show the viability of these ideas through the acceptance by the community, leveraging improvements that will make these solutions evolve collaboratively (Anderson, 2010, 2012; Gershenfeld, 2005, 2012).

In these collaborative spaces, the participation of all community members is nurtured, promoting equality of race and gender, benefiting from cross-knowledge, shared by every culture and subculture.

Teachers, researchers and students, young and more experienced, men and women of all races and religions, small business owners, inventors and entrepreneurs, members of the local community, all in a horizontal relationship, without titles or awards, just competence and mutual respect, working and learning from each other in a common space.

The purpose is to enhance the entry of women in more technical fields and Engineering, but also to attract students and professionals of Arts and Humanities, Design and Architecture, allowing them to materialize their ideas based on available and affordable technology, supporting creative inventions and aesthetic processes that will enrich the research and development results (R&D) (Blikstein, 2014; Troxler, 2014).

Teenagers and adults that abandoned formal education can find in these spaces the resources to start their own job and company.

It will be analyzed and described how Fab Labs, which are laboratories of digital fabrication, with broad educational, social and economic advantages, manage their knowledge in a formal and informal way, allowing every member to learn by watching and participate in

* Corresponding author.
E-mail addresses: smaravilhas@ua.pt (S. Maravilhas), joberto.martins@unifacs.br (J. Martins).

https://doi.org/10.1016/j.jbusres.2018.01.061
Received 18 August 2017; Received in revised form 23 January 2018; Accepted 26 January 2018
Available online 08 February 2018
0148-2963/

bigger communal projects.

The analysis of other existing Fab Labs makes possible to propose the introduction of best practices in these collaborative spaces, through benchmarking, avoiding mistakes and leaping steps for best performance.

2. Digital environments and the creation of knowledge

A collaborative space for stimulating innovation is a place of learning through the exchange and sharing of knowledge and experience (Hargadon & Sutton, 2002; Piscione, 2014) among its members, the Makers.

These spaces have several designations and typologies, like Makerspaces, Hackerspaces, Techshops and Fab Labs. The Fab Lab, or fabulous laboratory (Gershenfeld, 2005, 2012), is a laboratory of digital fabrication, serving as a prototyping platform of physical objects (Eychenne & Neves, 2013), with broad educational (Blikstein, 2014; Mandavilli, 2006), and social and economic advantages (Anderson, 2010, 2012; Troxler, 2014).

Makerspaces provide access to technologically advanced digital tools and machines, inserted in a network of participants, called Makers or Tinkerers, that can help answer questions and overcome obstacles (Anderson, 2010, 2012; Rifkin, 2011).

At the same time, allows to leverage innovation using technological resources available in the space, stimulating the creativity of its participants and enabling the development of products and solutions based on personal projects from ideation, or the construction supported on knowledge developed by other users, together, collaboratively, enhancing the results.

These Labs are used by everybody to enrich their projects, in a creative manner, inducing the creation of prototypes to leverage innovation, giving wings to their imagination and develop sustainable, social, local, economic innovative solutions to solve real problems.

Created in 2001 in the Massachusetts Institute of Technology (MIT) Center for Bits and Atoms (CBA), directed by Neil Gershenfeld, linked to the famous MIT Media Lab, created by Nicholas Negroponte in 1985, the first Fab Lab was funded by the National Science Foundation (NSF) from the United States of America (USA), and started based on the success of the course taught by Gershenfeld himself titled “How to Make (Almost) Anything” (Gershenfeld, 2012).

Eychenne and Neves (2013, p.10) mention that these Fab Labs are the “educational component of awareness to digital and personal fabrication, democratizing the conception of techniques and technologies and not just the consumption”.

To quickly realize the viability of the solution, the machines and tools available in the space will allow developing a prototype that, if it's not feasible, will lead to the search for new solutions, learning with the community how to develop products that will be accepted and wanted in the market, performing an instant market research for evaluation (Caner & Tyler, 2015).

Fail early, fail cheap, fail always, continuing to learn and evolve so that entrepreneurship is encouraged and emulated by others.

Students are encouraged to be producers of knowledge and not mere passive recipients.

Fab Labs build bridges between the engineers and fabrication of high-tech products, and other actors usually more averse to technical and manual manufacturing.

When someone has a difficulty operating the equipment's or machines, they can learn by observing other experienced users working, or they can ask for help, guidance or training with them or a Lab technician, enhancing the capabilities of every member of the space. Tacit knowledge is shared among the members of the Lab, working together, watching and learning, with the ones who own it.

The typology of academic Fab Lab, created in universities or research centers, aims to develop a culture of learning by doing, giving students, teachers, independent inventors and entrepreneurs the opportunity to learn by doing, creating a multidisciplinary space open to the outside to receive different insights and inputs.

In such cases, funding depends on the university or research center where they are installed, as well as the purchase of equipment and materials necessary for their operation, having its educational aspect assured by Teachers and Postdoctoral Fellows (Eychenne & Neves, 2013, p. 18) that support the management and maintenance of the space and its dynamics.

Working in a network, like the Internet supporting them, there are currently 1214 Fab Labs worldwide, facilitating the sharing of information and knowledge, connecting people and organizations and, thus, enabling the collaborative innovation (Hatch, 2013; Troxler, 2014).

These spaces aim to develop access to knowledge of science and engineering (Blikstein, 2014). Other users of the space, like students or experts in some technical area, share their know-how through courses or just by participating in collaborative projects.

3. Knowledge management, creation and sharing

Organized and contextualized data becomes information through contextualization, categorization, calculus, correction and condensation (Davenport & Prusak, 1998, p. 6). Information interiorized and applied to a practical task or function, once dominated by the user, becomes knowledge through comparison, consequences, connections and conversation (Davenport & Prusak, 1998, p. 7). Knowledge derives from data and information. Knowledge generation occurs when information is compared, combined, analyzed, and rearranged by people. Action is important to transform information in knowledge.

Knowledge is inside people's head, not in computers and databases. In a book or scientific paper there's the knowledge of the author, what he/she knew and could made explicit to others, which is only a small part of what he/she really knows. For the reader, there is only data and information there, until it's possible to act upon that information and integrate it in a process where we can apply what was read and do it ourselves with proficiency (Davenport, 2007; Davenport & Prusak, 1998). Knowledge is related with action. Someone can read all the books and articles about riding a bicycle. It will be helpful undoubtedly. But, only when someone act with the information received and pedal while maintaining equilibrium, is common sense to accept that the knowledge to ride the bicycle exists, and, curiously, will never be forgotten. That's why learning mathematics implies solving problems and perform hundreds of exercises. No one learns mathematics just by reading books or reports, or watch the teacher solving problems in the blackboard. Although useful, it's not enough. Medical Doctors perform dissections to learn about the human body. They don't just read books. That part is also needed, but we must do it ourselves to learn and internalize the sequences and mechanisms to adopt.

That type of knowledge is called tacit. Socrates, the Greek Philosopher, used to say that a person only knows something when it's possible to teach it to another person, with the same results.

Tacit knowledge can only be learned through practice and experience and is what we call know-how, that knowledge that is acquired through life, but very difficult to explain to others (Buckley & Jakovljevic, 2013). Constituted by subjective insights, intuitions and hunches of individuals, it's not easily communicated or shared. To gain access to such knowledge one may have to be practicing in other related areas of knowledge. What is held in someone's head and includes facts, stories, biases, and insights.

According to Davenport and Prusak (1998, p. 214) we shouldn't learn anything without relating that apprenticeship with practice. They believe that a healthy tension between knowledge and action is the key to the organizational success and, probably, the individual success also.

Trying to make that knowledge available to others, since it is ingrained in people's heads and attitudes, it's imperative to turn it explicit. Explicit knowledge is obtained from facts, from information, almost always through formal education. It is expressed through metaphors, analogies, concepts, hypothesis or models. It's the key for the creation of new knowledge. It is codified, communicable through formal and systematic language. It can be stored in manuals, documentation, patents, blueprints, reports and other accessible sources.

Tacit knowledge is subjective. It is knowledge obtained from experience, with the body, simultaneous, here and now, and analogous, related with practice.

Explicit knowledge is objective. It's a rational knowledge, with the mind, sequential, there and then, digital, related with theories (Nonaka & Takeushi, 1997, pp. 67).

The process of generating and converting knowledge has four phases. Explicit and tacit knowledge complement each other and, through their interaction, create new knowledge. According to Nonaka and Takeushi (1997, pp. 67; 83), the four phases are:

I) Socialization – from tacit to tacit knowledge. Creates shared knowledge. It's a process of sharing experiences, like mental models or technical competencies. This is what happens when someone in an apprenticeship learns with its master. Can be obtained directly from others, without using language, through observation, imitation, and practice.
   ⋙ In Fab Labs, people learn by watching, imitating and practicing with their peers. Different backgrounds and experiences allow internalizing different procedures and activities;

II) Externalization – from tacit to explicit knowledge. Creates conceptual knowledge. Tacit knowledge becomes explicit through dialog and collective reflection using metaphors, analogies, concepts, hypothesis and/or models. Books, reports and journal articles are examples of explicit knowledge through externalization. It combines deduction and induction.
   ⋙ In Fab Labs, Makers document their projects, especially on open days when the use of the space is free, and share it so others can learn and improve upon that knowledge, avoiding mistakes and adopting the best practices that conducted to those results so their projects can be successful too;

III) Combination – from explicit to explicit knowledge. Creates systemic knowledge. Combining different sets of explicit knowledge allows the creation of some new knowledge. Through education and formal training in schools and universities, different explicit knowledge from the combination of books, texts, activities and the different disciplines combined, generates some new knowledge that can be further developed with time. Computer databases can help categorize some explicit knowledge conducting to new knowledge.
   ⋙ In Fab Labs, users can search and retrieve documents from different projects from all the Fab Lab world network, in databases involving different disciplines like mechanics, robotics, electrical and computing engineering, design and other aspects that can help solving their own problems and give insights for the construction of new solutions or surpassing technical problems;

IV) Internalization - from explicit to tacit knowledge. Creates operational knowledge. The process of incorporating explicit in tacit knowledge, it is related with learn by doing. When internalized in the knowledge base of every individual as mental models or technical know-how, those experiences through socialization, externalization and combination become valuable assets.
   ⋙ In Fab Labs, Makers learn from the analysis of technical documentation and the projects of their peers worldwide, internalizing the new knowledge and consolidating it in its practical use in their projects, learning by doing. That way new knowledge and procedures are integrated to the way of doing things by Makers that can advance to new levels of know-how.

To make the creation of organizational knowledge viable, the tacit knowledge accumulated needs to be socialized with other members of the organization, starting, that way, a new spiral of knowledge creation that will pass the four phases again, generating new knowledge in an increasing successful non-stopping activity (Nonaka & Takeushi, 1997, pp. 79–83).

A new vision must be considered in relation to knowledge and the role it plays in organizations. The efficient exploitation of knowledge as an economic resource and one of the production sectors has become a factor of strategic, economic, social and political importance (Choo, 1996, 2003).

If, on the one hand, an organization cannot function without information and knowledge, on the other it is important to know how to use this resource to improve its use.

Thus, the faster the identification of the relevant knowledge to the organizations and the quicker the access to it, more easily their goals will be achieved (Terra, 2001).

Intellectual Capital, is a competence, skill and/or entrepreneurial intelligence and is recognized as an intangible asset of superior value for organizations (Edvinsson & Malone, 1998; Stewart, 1998, 2002; Sveiby, 1998).

But, most important is that information and knowledge play a key role in business since they affect the competition at three levels (Harvard Business Review, (Ed), 2001):

I) Modifies the industrial structure and, therefore, changes the rules of the competition (Stewart, 1998, 2002);
II) Creates competitive advantage for organizations offering new ways to overcome their rivals (Sveiby, 1998; Terra, 2001);
III) Creates new business opportunities, most often from the organization's internal processes (Almeida, Freitas, & Souza, 2011; Neto, 2013; Rodriguez, 2013).

Fab Labs should follow some recommendations to successfully achieve their goals, such as: Value and manage knowledge as a resource so or more important than any other that it needs to function (Maravilhas, 2015); Pay attention not only to the internal knowledge generated within the Lab, necessary to carry out the organizational tasks it undertakes, but also external knowledge, from various Fab Labs worldwide, to maintain their activity cost-effective.

Effective Fab Lab managers should not look at the cost of obtaining and retain all the knowledge needed to increase the successful projects of the Lab. They should consider, instead, how much will be lost if they don't have it (Maravilhas, 2013).

3.1. Knowledge management, creation, and transfer in Fab Labs

In this definition, all the practices that organizations use to represent, create, identify, and distribute knowledge, usually with the support of the computer and Internet, come together. In many organizations, a Chief Knowledge Officer (CKO) exists, and mediate all the programs between the workforce and the Board of the organization.

Almost all the for-profit companies depend on technology and software for their knowledge management projects like: knowledge repositories, knowledge bases, expert systems, corporate intranets and extranets, collaborative websites, like wikis, and document/content management software, that allow and promote the knowledge sharing and transfer process between its members (Bencsik, 2017).

Knowledge management focuses mainly in the mechanisms used to share and transfer the knowledge assets.

Currently, innovative products are developed based on rapid prototyping in universities R&D departments and research institutes, and in some larger companies. Only a small group of experts has the possibility of making prototypes in a short period of time and using simple means and resources (Anderson, 2010, 2012). In a Fab Lab, this process is democratized and any new technologies are taught so that everyone can enjoy the space and equipment's.

Knowledge shared is new knowledge created.

In relation to its effectiveness, since 2001 at MIT and since 2005, when the first Fab Lab was created outside of MIT, the model has proved to be a facilitator for the creation of regional innovation, building bridges and relationships between experts in technology, design, education, small business owners and entrepreneurs, architects, artists, non-profit organizations, etc.

The idea of a Fab Lab rests on social interaction, in projects involving both academics and craftsmen, the handyman and garage skilled inventors, bringing to the manual and practical learning the ones that in recent years have distanced themselves from the technology and have chosen a more intellectual and less physical training, less hands-on.

The interaction between people with such diverse skills and features, along with the acquired training on the use of the available equipment's, will allow a creative and stimulating environment thanks to the power of intellectual and cultural diversity, and the knowledge exchanged this way.

These spaces aim to develop access to knowledge of science and engineering, democratizing the practice of using the technics on the proposed projects (Blikstein, 2014), providing training courses to the community on the use of the equipment's available in the space, allowing the use of machines to carry out participants own projects or to participate in collaborative projects of the Fab Lab network (Walter-Herrmann & Büching, 2014).

All the projects are registered and shared so other Makers can replicate them freely, all around the world, making this new explicit knowledge free to the Fab Lab community.

As for the potential of transfer of the generated knowledge, the Fab Lab benefits from an extensive worldwide network which promotes the adoption of knowledge created in several laboratories spread across several continents, allowing to test the acceptance of a huge number of potential users and adapt, improve or complement the initial versions with the feedback obtained in this way (Dodgson & Gann, 2014).

Regarding the interdisciplinary collaboration, this is enhanced, as mentioned above in Section 2, by the number of technical, academic and skillful handy men that will cross the space and contribute with tips, advices, warnings and suggestions.

Several areas of knowledge are present in these spaces, such as: engineering, electronics, mechanics, computer science, architecture, design, physics, chemistry, administration, fine arts, crafts, and humanities.

This mix turns the space into a melting pot of cultures and sciences that will enable all to teach and to learn, enriching each of the worldviews involved and profiting all with the multiplicity of the knowledge obtained.

Several examples demonstrate the importance of these places for science and technology education, like learning concepts of Engineering and Mathematics (Blikstein, 2014), stimulating creativity and the development of inventions that allow to solve local problems of the communities where these Labs are located, promoting innovation and social economy, empowering people who are part of these networks allowing them an autonomy never imagined before (Mandavilli, 2006; Troxler, 2014).

Because all materials from the projects are made available to the entire network, the potential of dissemination of information allows building on prior knowledge, leveraging innovation and maximizing the previous research (Nonaka & Takeushi, 1997). That way, the open innovation and the ascent innovation are privileged (Eychenne & Neves, 2013, pp. 45, 61), transforming the Do It Yourself (DIY) model in Do It With Others (DIWO), or Do It Together (DIT), maximizing the educational and research function, with social and local impacts.

Working and learning collaboratively enhances the result of the projects, because it's possible to do a sort of market research immediately, getting feedback on how to improve your idea and prototype, failing fast and cheap, allowing to make a better model with the suggestions of the community, using crowdsourcing and the wisdom of the crowds.

With a markedly educational and research side, interdisciplinary, multidisciplinary and intradisciplinary (Blikstein, 2014; Troxler, 2014), it will allow to develop innovative projects of high scientific quality and high social relevance, following the model "faster, higher, better, more precise", determined by the Fab Lab network. This will be achieved by following the criteria of effectiveness, transfer of knowledge potential, originality and interdisciplinary collaboration.

The advantage of being based on an international model that has been tested, offers a place with an innovative atmosphere that will make possible the exchange of knowledge based in fortuitous but fruitful encounters among its members, like what happens in the more innovative companies like Google, IDEO, Idealab, Pixar, Apple, among others (Dodgson & Gann, 2014; Isaacson, 2011, 2014; Kahney, 2009, 2013; Majaro, 1990).

A Fab Lab attracts more actors from companies than the university itself can do. With its innovative DIY concept, opens innumerous possibilities for universities and ensures a productivity index that will be relevant to the increased volume of innovations, and the consequent creation of wealth resulting from it.

4. Research methodology and results

4.1. Research methodology

The methodology used for the successful development of the project consisted, to begin with, on bibliographic analysis from books, journal articles, websites, thesis and reports, allowing to understand the subject, its stakeholders, shareholders, and other participating entities. Some interviews with key players in the Fab Lab world have helped to structure the project and the knowledge shared helped avoiding some major obstacles and implementation problems that have been dealt with by other Labs in Brazil, Portugal, Italy, Spain, and France.

Seven Fab Managers from our LinkedIn connections were chosen, depending on their availability to answer by Skype to some questions in a personal semi-structured interactive interview, making it a non-probabilistic sampling designated as convenience sample.

The questions asked were interpretative and leading, trying to obtain the opinion, experience, and knowledge of the experts interviewed.

Content and narrative analysis were performed for the treatment of the data obtained. The answers were transcribed word by word, into an excel sheet, using a deductive approach, useful to group the data and then look for similarities and differences.

Themes, coding, coding sorts, and indexing were used to analyze the data and identify an explanatory framework or coding plan.

Descriptive and interpretative analysis, identified recurrent themes.

4.2. Results

According to the analysis of these seven semi structured interviews performed with the Fab Managers of one Portuguese Lab, one Spanish Lab, one French Lab, one Italian Lab, and three Brazilian Labs, in almost all the Labs, examples of Makers that had benefited from the information sharing in the Lab exist, but especially in oral form. The written documentation is not as valued as the oral transmission and the observation experienced.

In almost all the Labs, users check other Makers files for inspiration, but usually just in the files from their own Lab. Only in bigger projects, conducted by more experienced users, and involving several Labs, the files from other Labs are retrieved for getting insights for the new project at hand or for problem solving. In other Labs files, there is no habit of doing so, letting creativity flow only from the participants of the projects, without inspiration from their peers' previous projects.

Usually, users record their projects in their own language for easiness of the task (in English, in Dutch, in Spanish, in French, in Afrikaans, in Tsonga, in Xhosa, in Portuguese, in Italian, in several Chinese dialects, and so on). This makes very difficult the retrieval of information and the appropriation of knowledge, because the linguistic differences will make very hard to analyze and interpret the information gathered by other interested Makers from other countries. Photos, designs, videos, and schemes, are very helpful and should be always included.

The privileged form of information and knowledge exchange goes to videoconference solutions available in all the Labs. Seems to be easier for Makers to watch and debate with their peers, than to read what has been done previously. It's a form of transforming the tacit in explicit knowledge.

All this information should be in English for the use of other Makers in other countries or, at least, have an English Abstract for international user's aid. The Abstract can be done with the Fab Director or Fab Guru help, or using a web translator. A Lab colleague can help performing this task.

This information can be made available in a Cloud Server maintained by the Fab Foundation, allowing the access to everyone involved to improve results and knowledge sharing.

Although a lot of computer specialists frequent the Labs, their core business is not managing knowledge. They are more concerned in developing new products or solutions, than in maintaining and sharing the knowledge created in the space.

Databases can be used to assist in the information visualization and finding from all the Labs, along with other technology solutions that allow searching by keyword, subject, title, name or codename of the Makers, subject area, country, city, and so on, mixing them all to filter the results.

That way, the knowledge sharing will be improved.

From the answers collected is possible to perceive that the practices are common among the Labs because they all operate according to Fab Foundation guidelines and regulations.

No cultural aspects and differences were noted influencing the practices adopted by each lab besides the language factors.

Best practices are always disseminated among the network of Labs and adopted every time an improvement is made and functioned.

No questions were performed about the physical conditions of the Labs to minimize the time available given by the Fab Managers to the researcher.

Table 1 presents a summary of findings for easy understanding of the main findings of the research.

5. Examples of solutions created in fab labs using collaborative knowledge

There are several examples of original products created in Fab Labs that originated innovations shareable among all the Labs. “Once prototyped the object and tested the processes, the project can easily be replicated by other Fab Labs in the network” (Eychenne & Neves, 2013).

Some examples of innovations produced in these spaces include (Gershenfeld, 2012, pp. 48–50; Mandavilli, 2006, pp. 862–864):

1. Monitoring sheep herds using Global Positioning System (GPS) and radio frequency developed in Norway, and now used by anyone who needs a similar solution in any location of the world;
2. From the Boston Fab Lab, a project was started to make antennas, radios, and terminals for wireless networks, to provide Internet access. The design was refined at a Fab Lab in Norway, tested at another one in South Africa, deployed from one in Afghanistan, and now is running on a self-sustaining commercial basis in Kenya;
3. Circuit boards and computer chips produced by an eight-year-old girl in Ghana using an MIT design and methodology;
4. Also in Ghana, villagers built large ‘collectors’ to harness solar energy and built machines to grind seeds into *fufu* powder for their nourishment;
5. Puzzles 2D, convertible to 3D, were also produced by an eight-year-old girl in the USA (Neil Gerschenfeld's own daughter);
6. In Pabal, India, also based in a MIT model, farmers built sensors to measure the fat content in milk, allowing them to charge for a fair price to industrial buyers;
7. In South Africa, women that never had used a computer, now use it daily to design and send projects to the vinyl cutter, to create decorative products and accessories. Some are girls who left school due to a teenager pregnancy and here can find a profitable and dignifying activity;
8. Also in South Africa, other Makers produced a light switch controlled by cellphone, a motion-sensor light and an alarm system, very useful for their unsafe neighborhoods;
9. In the USA, a student produced a sensor that protects women from attackers that can come from behind them, opening a sharp edge spear.

Another way of exchanging knowledge developed from Makerspaces is the Maker Faire, “The Greatest Show (& Tell) on Earth. *Maker Faire* is part science fair, part county fair, and part something entirely new!”. Disseminated all around the world, the Maker Faire allows the exchange of knowledge through the exhibition of bigger projects developed by several Labs in the community.

All the examples show, and several others exist, that the common element in this new creative class is the fact that the creators have been consumers that wanted something previously inexistent. So, instead of being satisfied with the options available, they did something better for

Table 1
Summary of findings.
Source: Researcher analysis from the data collected.

Labs/questions	Portuguese Lab	Spanish Lab	French Lab	Italian Lab	Brazilian Lab 1	Brazilian Lab 2	Brazilian Lab 3
Are there examples of Makers that had benefited from the information and knowledge sharing in your Lab?	Yes	Yes	Yes	Yes	Yes	Yes	No
What is the preferred way of obtaining information and knowledge in your Lab?							
Written documentation?	No	No	Yes	Yes	No	No	No
Observation?	Yes	Yes	Yes	Yes	No	Yes	No
Oral transmission?	Yes	No	Yes	Yes	Yes	No	Yes
Video conference?	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Users of your Lab use to check other Makers' files for inspiration?	Yes	Yes	Yes	Yes	Yes	No	No
From files of Makers of their own Lab?	Yes	Yes	Yes	Yes	Yes	/	/
From files of Makers of other Labs?	No	No	Yes	Yes	No	/	/
What is the main reason preventing Makers from checking other Labs files?	Time	Language	Time	Language	Language	Language	Language
Could an English Abstract be a helpful resource to surpass the language barrier?	Yes	No	Yes	Yes	Yes	No	Yes

themselves (Anderson, 2012, p.81).

6. Conclusion

After describing the concept of Makerspaces, the analysis focused in a specific type: The Fab Lab. Several educational advantages promoted by these spaces were described, mainly in the learning of concepts related with Engineering, Calculus, Mathematics, and described the benefits from them to the attraction of women for these specific areas, and in the training of youngsters that didn't pursue their formal education, so they can have useful technical competencies for the labor market or to start a business on their own.

The different backgrounds of the Makers in the space will be potentially advantageous for the share and exchange of experiences and knowledge that will enrich all the participants. The Maker movement encourages Master Makers to transfer their knowledge of production techniques to Makers who are less experienced.

The knowledge created is shared among the network, allowing comments and improvement suggestions that will enrich the value of the projects (Stricker, 2014).

Some examples were presented to demonstrate the viability of these learning spaces and its creative and innovative advantages to empower the people involved, motivating them to create solutions based in rapid prototyping that allow to evaluate the potential of their invention and its acceptance by the community of Makers that can motivate the creation of a new business or improve the competencies at their current jobs.

The Fab Lab aims to develop a culture of learning by doing, giving students, teachers, independent inventors and entrepreneurs the opportunity to learn by doing it themselves (DIY), and learn together (DIWO or DIT) with other Makers from their Lab or another from the network, creating a multidisciplinary space, open to the outside, to receive different insights and inputs (Gershenfeld, 2005, 2012).

Information from projects, collective and individual, and from the courses to learn how to operate all the machines and equipment's in the Lab, together with rules and regulations about the use of the space, can be a knowledge disseminator task.

All this internal and external knowledge needs to be managed, to improve the knowledge creation among the users of the space (Sordi, 2008).

Although, without a general strategy implemented in all Labs, small steps adequate to the Labs publics and technology competence are being taken, being a starting point for a future best practice to be implemented in the entire Fab Lab network.

This research article contributed enormously to the scientific area of knowledge management, creativity and innovation, mainly because there are no scientific papers about this subject, relating Fab Labs and their creative and innovative impacts, and the role knowledge plays in it. Also, a wide description of the advantages promoted by these spaces is presented, enriching the management science and product development areas, filling the gap in the topic addressed.

Acknowledgments

To PNPD/CAPES for the 2nd Post-Doctoral Scholarship Grant.

Funding

This research was supported by a Brazilian PNPD/CAPES Post-Doctoral Research Grant, between June 2015 and August 2016.

References

Almeida, M., Freitas, C., & Souza, I. (2011). *Gestão do Conhecimento para a Tomada de Decisão* (1ª. Ed). S: Paulo: Atlas.

Anderson, C. (2010). In the next industrial revolution, atoms are the new bits. *Wired Magazine, I, 25*.

Anderson, C. (2012). *Makers: The new industrial revolution* (1ª ed.). New York: Crown Business.

Bencsik, A. (2017). *Knowledge management initiatives and strategies in small and medium enterprises.* Hershey, PA: IGI Global.

Beuren, I. (1998). *Gerenciamento da informação: um recurso estratégico no processo de gestão empresarial.* São Paulo: Atlas.

Blikstein, P. (2014). Digital fabrication and 'making' in education: The democratization of invention. In J. Walter-Herrmann, & C. Büching (Eds.). *FabLabs: Of machines, makers and inventors*. Transcript-Verlag: Bielefeld.

Buckley, S., & Jakovljevic, M. (2013). *Knowledge management innovations for interdisciplinary education: Organizational applications.* Hershey, PA: IGI Global.

Caner, T., & Tyler, B. B. (2015). The effects of knowledge depth and scope on the relationship between R&D alliances and new product development. *The Journal of Product Innovation Management, 32*(5), 808–824.

Chesbrough, H. (2003). *Open innovation: The new imperative for creating and profiting from technology.* Boston: Harvard Business School Press.

Choo, C. (2003). *Gestão de informação para a organização inteligente: A arte de explorar o meio ambiente.* Lisboa: Editorial Caminho.

Choo, C. W. (1996). The knowing organization: How organizations use information to construct meaning, create knowledge and make decisions. *International Journal of Information Management, 16*(5), 329–340.

Davenport, T. (1997). *Information ecology: Mastering the information and knowledge environment.* New York: Oxford University Press.

Davenport, T. (2007). *Profissão: Trabalhador do conhecimento: Como ser mais produtivo e eficaz no desempenho das suas funções.* Amadora: Exame.

Davenport, T., & Prusak, L. (1998). *Working knowledge: How organizations manage what they know.* Boston: Harvard Business School Press.

Dodgson, M., & Gann, D. (2014). *Inovação* (1ª ed.). Porto Alegre: L&PM Pocket Encyclopaedia.

Edvinsson, L., & Malone, M. (1998). *Capital Intelectual: Descobrindo o Valor Real de sua Empresa pela Identificação de seus Valores Internos.* S. Paulo: Makron Books.

Eychenne, F., & Neves, H. (2013). *Fab Lab: A Vanguarda da Nova Revolução Industrial.* Associação Fab Lab Brasil.

Gershenfeld, N. (2005). *Fab: The coming revolution on your desktop: From personal computers to personal fabrication.* New York: Basic Books.

Gershenfeld, N. (2012). How to make almost anything: The digital fabrication revolution. *Foreign Affairs, 91*(6).

Hargadon, A., & Sutton, R. (2002). Como Construir uma Fábrica de Inovação. *Inovação na Prática: On Innovation.*. (pp. 59–79). Rio de Janeiro: Campus.

Harvard Business Review (Ed.). (2001). *Gestão do Conhecimento: On Knowledge Management*(4th ed). Rio de Janeiro: Campus.

Hatch, M. (2013). *The maker movement manifesto: Rules for innovation in the new world of crafters, hackers, and tinkerers* (1ª ed.). McGraw-Hill Education.

Isaacson, W. (2011). *Steve Jobs* (1ª ed.). New York: Simon & Schuster.

Isaacson, W. (2014). *Os Inovadores: Uma biografia da revolução digital* (1ª ed). S. Paulo: Companhia das Letras.

Kahney, L. (2009). *A cabeça de Steve Jobs* (2ª ed.). Rio de Janeiro: Agir.

Kahney, L. (2013). *Jony Ive: O gênio por trás dos grandes produtos da Apple* (1ª ed.). S. Paulo: Portfolio-Penguin.

Majaro, S. (1990). *Criatividade: Um passo para o sucesso.* Lisboa: Europa-América.

Mandavilli, A. (2006). Make anything, anywhere. *Nature, 442*(8).

Maravilhas, S. (2013). A web 2.0 como ferramenta de análise de tendências e monitorização do ambiente externo e sua relação com a cultura de convergência dos media. *Perspectivas em Ciência da Informação, 18*(1), 126–137.

Maravilhas, S. (2014). Information quality and value. In Khosrow-Pour (Vol. Ed.), *Encyclopedia of information science and technology*(3rd Ed.). *vol. VI. Encyclopedia of information science and technology* (pp. 3981–3989). Hershey: IGI Global.

Maravilhas, S. (2015). Managing an information strategy project: The case of a real estate broker organization. In Jamil, Maravilhas, Malheiro, & Ribeiro (Eds.). *Handbook of research on effective project management through the integration of knowledge and innovation* (pp. 19–43). Hershey: IGI Global.

McGee, J., & Prusak, L. (1995). *Gerenciamento estratégico da informação: Aumente a competitividade e a eficiência de sua empresa utilizando a informação como uma ferramenta estratégica.* Rio de Janeiro: Campus.

Neto, R. (2013). *Gestão do Conhecimento em Organizações: Proposta de Mapeamento Conceitual Integrativo* (1ª ed.). S. Paulo: Saraiva.

Nonaka, I., & Takeushi, H. (1997). *Criação de Conhecimento na Empresa: Como as Empresas Japonesas geram a dinâmica da Inovação.* Rio de Janeiro: Campus.

Piscione, D. (2014). *Os Segredos do Vale do Silício: O que Você Pode Aprender com a Capital Mundial da Inovação* (1ª ed.). São Paulo: HSM.

Rifkin, J. (2011). *The third industrial revolution: How lateral power is transforming energy, the economy, and the world.* New York: Palgrave Macmillan.

Rodriguez, M. (2013). *Gestão do Conhecimento e Inovação nas Empresas* (1ª ed.). Rio de Janeiro: Qualitymark.

Sordi, J. (2008). *Administração da Informação: Fundamentos e Práticas para uma Nova Gestão do Conhecimento.* S. Paulo: Saraiva.

Stewart, T. (1998). *Capital Intelectual.* Rio de Janeiro: Campus.

Stewart, T. (2002). *A Riqueza do Conhecimento: O Capital Intelectual e a Organização do Século XXI.* Rio de Janeiro: Campus.

Stricker, U. (2014). *Knowledge management practice in organizations: The view from inside.* Hershey, PA: IGI Global.

Sveiby, K. (1998). *A Nova Riqueza das Organizações: Gerenciando e Avaliando Patrimónios do Conhecimento.* Rio de Janeiro: Campus.

Terra, J. (2001). *Gestão do Conhecimento: O Grande Desafio Empresarial.* S. Paulo: Negócio Editora.

Troxler, P. (2014). Making the 3rd industrial revolution: The struggle for polycentric structures and a new peer-production commons in the fab lab community. In J. Walter-Herrmann, & C. Büching (Eds.). *FabLabs: Of machines, makers and inventors*. Transcript-Verlag: Bielefeld.
Walter-Herrmann, J., & Büching, C. (Eds.). (2014). *FabLab: Of machines, makers, and inventors*. Bielefeld: Transcript-Verlag.

Sérgio Maravilhas is a Lecturer at UNIFACS and SENAI/CIMATEC, Brazil. Having two Post-Docs, one from UFBA and another one from UNIFACS, both with PNPD/CAPES Grants, he has a PhD in Information and Communication in Digital Platforms (Porto University and Aveiro University, Portugal), a Master in Information Management (FEUP and Sheffield University, UK), a Postgraduate Course in ICT (FEUP), a Specialization in Innovation and Technological Entrepreneurship (FEUP and North Carolina State University, USA) and a five years Degree in Philosophy, Educational Branch (FLUP). A Teacher and Trainer since 1998, worked at ESE-IPP as a Supervisor at the *Internet@School* project between 2002/2005, and a University teacher since 2005 at Aveiro University (DEGEI), and since 2010 at ULP and IESFF in Masters and MBA levels. Teaches Marketing, Research Methods, Innovation Management, Creative Processes in Innovation, Intellectual and Industrial Property, Technology Watch, Information and Knowledge Management, Information Systems, and Organizational Behavior in Universities and he is a trainer in ICT, Sales, Negotiation and Neuro-Linguistic Programming (NLP).

Joberto Martins has a PhD in Computer Science at Université Pierre et Marie Curie (Paris VI), Paris (1986), Post-Doc at ICSI/Berkeley University (1995) and Post-Doc Senior Visiting Researcher at Evry University – France (2016). Invited Professor at HTW - *Hochschule für Techknik und Wirtschaft des Saarlandes* (Germany) (since 2004) and Université d'Evry (France), Full Professor at Salvador University, Head of NUPERC and IPQoS research groups with research on Resource Allocation Models, Autonomic Computing, Software Defined Networking/OpenFlow, Internet of Things (IoT), Smart Grid and Smart Cities. Active presence in the international research community on journal editorial boards, diverse steering committees, IEEE Senior Member and current chair of the IEEE CGAA (Committee on Global Accreditation Activities). Member of the governors' board of the FAPESB (Bahia Research Funding Agency) and *AdHoc* consulting member of diverse research funding agencies - IEEE, IFIP, FAPESB, FACEPE, FAPEMIG, RNP, FINEP, CNPQ, CAPES and INEP.