The Maker Movement across North Africa

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Abstract

This Working Paper sets out findings from research exploring the growing maker movement across North Africa, focusing primarily on Egypt, but also highlighting experiences from Morocco and Tunisia. Based on data gathered through interviews with 13 management-level individuals involved in 10 different makerspaces—seven in Egypt, two in Tunisia, and one in Morocco—the authors present findings related to the operational dynamics of these makerspaces; linkages between innovation, learning and skills development; issues of innovation ownership, intellectual property (IP) appropriation, and collaboration; and the notion of innovation scalability.

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Keywords

maker movement, entrepreneurship, innovation, learning, skills development, innovation ownership, intellectual property (IP), scalability, sustainability, North Africa, Egypt, Tunisia, Morocco

I. Introduction

North Africa continues to experience unprecedented change in the aftermath of the Arab uprisings that swept across the region starting January 2011. The uprisings expressed the persistent demands to ameliorate political, social and economic exclusion, evident in, among other things, the persistent unemployment of the predominantly young population. In North Africa, the unemployment of youth, defined as those aged 15-24, was recorded at 29.5% for 2015 (ILO, 2016). The share of the youth, those between the ages of 15-24, in the total population was recorded at 17.4% for Egypt, 17.4% for Morocco, and 15.5% for Tunisia in 2015 (ILO, 2017).

The Arab Spring itself was triggered by a Tunisian informal entrepreneur, Mohamed Bouazizi. Like many others faced with unemployment, he had to resort to the informal economy and work as a street vendor. Bouazizi publicly set himself ablaze on 17 December 2010, representing a cry for economic inclusion that echoed across North Africa and resulted in the overthrow of the authoritarian regimes in Egypt and Tunisia.

Amidst the socioeconomic and political flux in North Africa, a number of spaces have emerged for makers, hackers and entrepreneurs to meet and collaborate in Egypt, Tunisia, and Morocco. In addition to providing access to technological resources, these spaces provide a platform for young makers, students, and potential entrepreneurs to reach out and connect to key players in the formal market. These key players include universities and private sector and public sector stakeholders, all of whom collaborate with the makers to create a virtuous cycle of innovation. While alternative modes of innovation and creation have historically been neglected by a majority of African policymakers due to the "unconventional nature of their enterprises", recent years have witnessed a sharp increase across the continent in civic participation in—and researcher and policymaker interest in—the maker movement. The African movement is especially significant because it empowers citizens to use their local expertise and skills and transfer this know-how into solution- oriented innovation that targets problems that exist in their daily lives (Ekekwe, 2015).

Makerspaces, which provide tools to entrepreneurs and other individuals, also provide access to technologies. This presents youth and potential entrepreneurs with opportunities to access sophisticated technologies and means of production at low costs. One of the unique attributes of the maker movement is that the creative process of making is shared with others, allowing others to improve and build upon innovations. This is similar in concept to the free and open source software (FOSS) movement, whereby codes are freely available for individuals to build on and improve. Van

Holm (2015) refers to the maker movement as a "second industrial revolution". Unlike in the first industrial revolution, sharing is seen as culturally acceptable in this second industrial revolution, in contrast to the predominance of industrial secret-keeping in the past (Van Holm, 2015). This sharing serves to fulfill the promise of the public good characteristics of knowledge, notably non-rivalry, where the value of knowledge increases rather than diminishes with use and sharing.

The study on which this Working Paper is based aimed to map and explore the maker movement phenomenon across North Africa, focusing primarily on Egypt, but also highlighting experiences from Morocco and Tunisia. This Working Paper aims to contribute to the literature about makerspaces in North Africa, as most existing maker-oriented literature focuses on other areas of the African continent. The objectives of the research were to develop an understanding of how existing makerspaces operate, to identify the types of innovation taking place in the spaces, and to probe into issues of innovation ownership and intellectual property (IP) appropriation in these spaces. Our study also enquired about matters of scalability at the spaces, and attempts at linkages between makerspaces and entrepreneurship.

II. Study Background and Context

A. What are Makerspaces?

Makerspaces are physical spaces with tools, where individuals of different backgrounds design, prototype, and create manufactured works. Makerspaces can take various forms, whether it is "loosely-organized individuals sharing space and tools, for-profit companies, non-profit corporations, organizations affiliated with or hosted within schools, universities or libraries…" (Makerspace, 2017). Makerspaces provide individuals with access to equipment, community, and education that individuals would not have had access to on their own. Such spaces also act as areas of knowledge exchange and sharing. Additionally, makers who are knowledgeable about one tool can aid large numbers of other innovators, and vice versa: "One capable craftsman with a […] 3D printer can provide improved manufacturing services and specialized components for hundreds of artisans; similarly, a technically literate artisan with a computer […] can assist hundreds of […]mechanics." (Waldman-Brown et al., p. 13).

According to Good (2013), who has studied makerspaces extensively, these spaces transform collective knowledge into a physical or digital product. This final product keeps getting revised and improved upon and the evolving process of that product reflects the learning that takes place in a makerspace. The process usually starts with identifying a problem, followed by drafting ideas on how to solve that problem, then creating the product, and finally reflecting on and revising that product. Ekekwe (2015) sheds light on some of these digital and physical products—including Kenya's M-PESA mobile payment system, and the BitFinance start-up in Zimbabwe—to emphasise how makers in the African continent are shaping the future.

When examining the dynamics of makerspaces, Dougherty (2012) finds that the word "maker" is more relevant than the word "inventor". The concept of an inventor raises very high expectations for revolutionary products to appear and dismisses the minor tinkering and educational processes that take place in the makerspace environment. Furthermore, very few people see themselves as inventors, but many view themselves as individuals making new products (Dougherty, 2012).

i. Makerspaces, Entrepreneurship, and Innovation

The maker movement phenomenon has been on the rise in developing countries in an effort to address local problems in innovative ways at low costs. Makerspaces contribute to human resource development through their ability to create entrepreneurs, even by accident (Van Holm, 2017). In this context, we can draw a parallel between makers and "lead users", a term coined by Von Hippel (1986) to describe those who identify needs for products that are "general to a market place", but identify these needs before their market demand arises. In other words, lead users are users of a product or service who currently experience needs still unknown to the majority of the public, and therefore benefit greatly if they obtain a solution to these needs before others do so. Lead users generally start firms based on the solutions they develop, similar to makers who usually create a product to solve a personal problem without realising that a market demand exists for such a product. Makerspaces provide an open collaborative space that is inviting to entrepreneurs who want to innovate, and also to those more focused on the "making" without having an overtly entrepreneurial mindset.

Furthermore, makerspaces in developing countries have the opportunity to benefit from open source appropriate technology (OSAT), which encourages innovation by using mostly open designs and blueprints. This allows for imported technologies to be adapted and altered to meet local developmental needs (Dougherty, 2012). Combined with the lower costs of 3D printers, OSAT helps locally manufacture objects that would otherwise be costly to import and manufacture in remote locations. In rural areas specifically, makerspaces present an opportunity to utilise and build upon otherwise unused and under-utilised machinery. For example, the RepRap open design 3D printer, which is often found in makerspaces, is an open source desktop 3D printer capable of printing plastic objects. The printer is portable making it easy to transfer between various rural areas. It also has the ability to custom manufacture any open source materials that are needed for the price of about US $30 per kg (King, Adegboyeg, Rozario, & Pearce, 2014).

ii. Makerspaces and Skills Development

Makerspaces and the maker culture have the potential to transform educational institutions (Dougherty, 2012). This transformation can take different forms, depending on the type of makerspace and makerspace users. Nevertheless, there are commonalities among makerspaces in relation to learning, which allow makerspaces and their users to take on attributes of what can be referred to as a "community of practice" (see Sheridan et al., 2014). Within a makerspace, there tends to be a formal learning component along the lines of the traditional teacher-to-student model, but at the same time a strong, non-hierarchical, informal element in which users exchange skills, experiences and ideas. This prioritisation of peer-to-peer knowledge-sharing is one of the key, transformational characteristics of the maker movement.

Learning takes places in different types of makerspaces, whether they are stand-alone or community driven. Stand-alone makerspaces are the most sophisticated type of makerspace, and they require a membership for people to use them. Community spaces and drop-in spaces are more accessible to the general public, but are usually geared towards smaller projects. The learning process, and associated skills development, that takes place within these makerspaces usually cannot be measured in units at an individual level. Learning is better measured by the community's capability to produce improved products rather than by the raw knowledge of individuals. Therefore, we can

say that the maker movement is viewed as more of an extension of the education landscape (Sheridan et al., 2014).

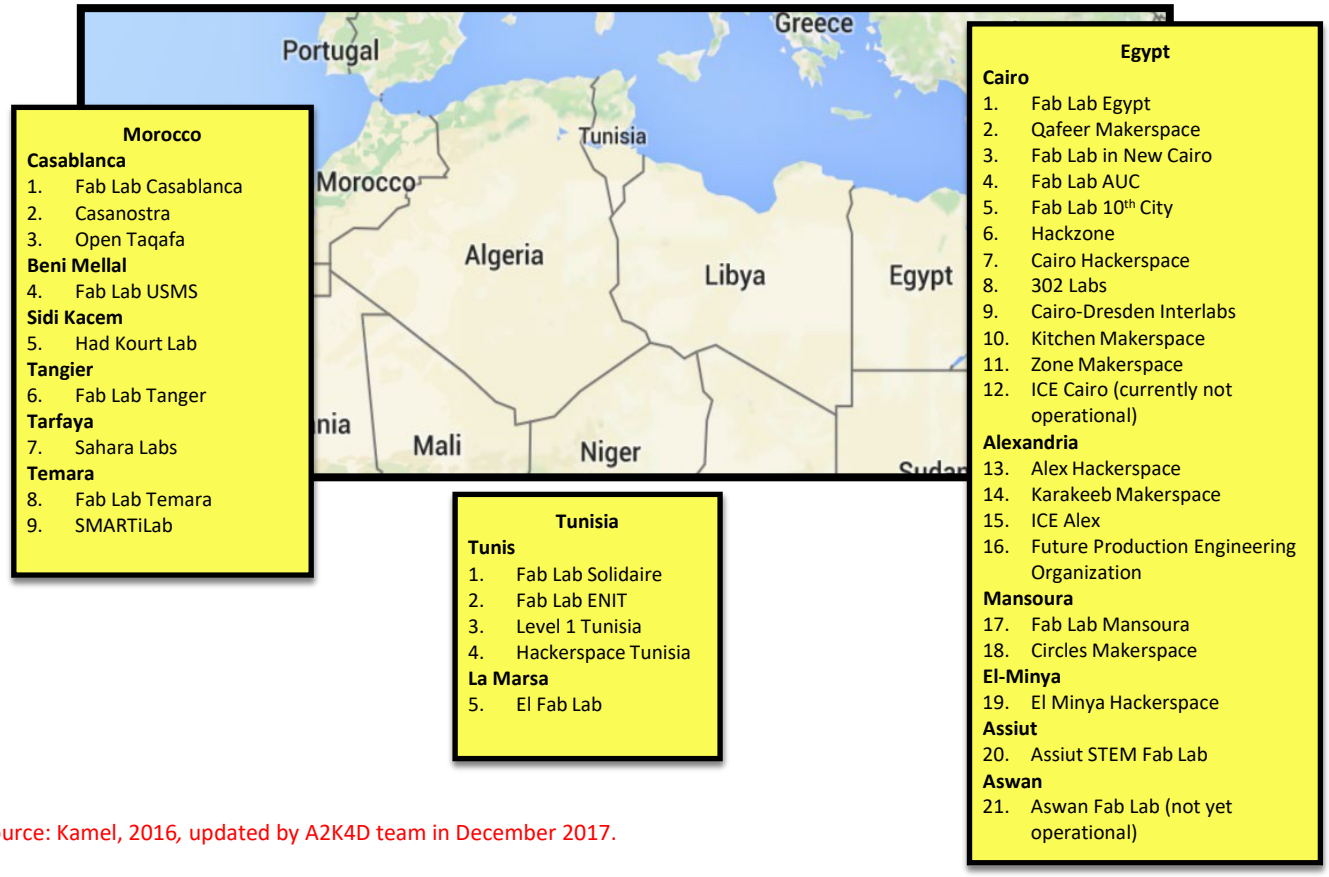
Despite the differences in the scale of projects, participants, and funding, makerspaces all share an ethos of using the creative process to share knowledge. Unlike in formal schooling, work and learning are more voluntary. Even amongst the structured learning that takes place in makerspaces, individuals join workshops voluntarily to gain knowledge, whether they are "pro-makers" or "pre-makers". Pro-makers are those with an advanced knowledge of using the various machines offered at makerspaces to create different innovations, but seek to learn how to develop their innovations into products that can be launched into the market. Pre-makers, on the other hand, are those who are new to the maker scene and are looking to gain knowledge on self-manufacturing using the tools offered at makerspaces, even if these innovations have no economic or financial viability (Sheridan et al., 2014).

B. Makerspaces across North Africa

Although the maker movement in Egypt, Tunisia, and Morocco is still nascent, there is a notable increase in the number of spaces opening up in different cities in the three countries. Most makerspaces in North Africa are community-based and mainly function separately from educational institutions or libraries. This is in contrast to the prevalence of makerspaces in educational institutions and libraries in other areas around the world. Reasons for this include limited funding for public libraries in North African countries, in addition to the limited existence of public libraries in certain countries.

Figure 1 below is a visual representation of makerspaces identified in the three selected countries of study. Although not comprehensive, the list of makerspaces gives an indication of the makerspaces with online presence in each country, in addition to the geographical spread of makerspaces across different cities in each country.

Figure 1: Makerspaces across North Africa



Source: Kamel, 2016, updated by A2K4D team in December 2017.

The presence of makerspaces in Egypt, Tunisia, and Morocco increased after the Arab uprisings of 2011. In response to millions of individuals struggling to find decent jobs, facing difficulties in establishing private entrepreneurial ventures, or resorting to the informal market, a number of platforms emerged to harness the creativity and imagination of many. With a strong focus on hardware entrepreneurship, makers and hackers have gathered in labs and makerspaces, with communities forming around a common desire to create and make. It is increasingly argued that it is vital that these innovators receive financial and logistical support, as this emerging phenomenon of collaborative and digital fabrication within the African maker movement has the potential to transform dynamics in a variety of industries in Africa as a whole (see Ekekwe, 2015).

Makerspaces have also emerged as a bridge connecting knowledge creation with entrepreneurship for many young graduates as they come to see the gap between what is taught in a classroom and what is needed in the job market. Incubators, accelerators, and other entrepreneurial agents in these countries have financed a number of prototypes designed and engineered by makers, with a few of these prototypes successfully transformed into scalable commercial products. Crowd-funding platforms have also become popular intermediaries for many makers to generate an initial buzz and interest in their designs across the region and to raise a first round of seed funding.

Some of the makerspaces we identified in North Africa have been founded in line with the Fab Foundation, an organisation that emerged out of the Massachusetts Institute of Technology (MIT) Center for Bits and Atoms Fab Lab (short for Fabrication Lab) programme. The Fab Foundation was created in 2009 to "provide access to the tools, the knowledge and the financial means to educate, innovate and invent using technology and digital fabrication to allow anyone to make (almost) anything, and thereby creating opportunities to improve lives and livelihoods around the world" (Fab Foundation, n.d.). Knowledge-sharing is key to this global network of makerspaces. The Fab Foundation supports a global Fab Lab network that enables makers to connect, collaborate, and innovate beyond the parameters of national borders. According to the Fab Foundation, a Fab Lab is defined as a technical prototyping platform for innovation and invention, providing stimulus for local entrepreneurship. A Fab Lab is also a platform for learning and innovation: a place to play, to create, to learn, to mentor, and to invent (Fab Foundation, n.d.). The most important advantage of integrating with the global Fab Lab network includes the core aspiration of the maker movement: knowledge-sharing. The network enables makers around the world to connect and combine the creative power of each network member in order to educate, innovate, and invent collaboratively (Fab Foundation, n.d.). Egypt, Tunisia, and Morocco each host several Fab Labs associated with the Fab Foundation, alongside other types of makerspaces that have also been identified in each country.

III. Research Design and Questions

We undertook desk research to map the maker movement in Egypt, Tunisia and Morocco, and we carried out fieldwork to explore the dynamics within makerspaces in the three countries. The fieldwork looked into the types of settings in which innovation was taking place, as well as the interactions between different players in the makerspaces. During the fieldwork, our main method of data collection was semi-structured interviewing (based on the questionnaire provided in Appendix I). Semi-structured interviewing guided by interview protocol was used, in line with other makerspace research in Africa (see Kraemer-Mbula & Armstrong, 2017).

The interviewing sample consisted of 13 individuals involved in makerspaces in Egypt, Tunisia and Morocco. These included nine people involved in running seven makerspaces examined in Egypt, two makerspace staff members involved in running two makerspaces in Tunisia, and two people running one makerspace in Morocco. In-depth semi-structured interviews, which were audio-recorded and subsequently transcribed, were preferred for the sample, given that little information was known beforehand about the makerspaces and their operations, i.e. the business models, the problems and successes encountered, and the types of innovation occurring in different spaces. Interview data were coded and analysed according to each research sub-section.

Based on our mapping of the existing makerspaces in Egypt, Tunisia, and Morocco, we identified the spaces by country, city, and their affiliation (if any). We used purposive sampling to select the makerspaces included in the study. The choice also depended on established contacts in each country, as the response rate for interviews was low.

Research questions were largely grouped into six categories (see Appendix I). First, to complement the desk research, we asked about the makerspace model being followed. Second, we asked about the types of innovation, learning, and skills development that occurred in the makerspace. Third, we

asked questions related to intellectual property (IP) and ownership issues at makerspaces. Fourth, we enquired about scalability. Fifth, we asked about measuring the innovation that occurs in the makerspace. Last, we got feedback for policy recommendations, which we present at the end of this Working Paper, in the "Conclusions" section. Qualitative interview results were categorised to inform the research results.

There is little empirical research on the maker movement in North Africa, and makerspaces have yet to produce tangible outputs that researchers can use to measure their contributions. The research findings generated by this study lay the foundation for further studies on the maker movement and provide information to better understand the operational dynamics of makerspaces.

This study provides insights that can potentially be useful to policymakers because it addresses matters related to employment, cost-effective modes of skills development, and avenues for entrepreneurship. If makerspaces result in user innovation that yields employment opportunities, then countries in North Africa should support and nurture these spaces as an investment for their youth populations. The study findings point to the dire need for a sustainability model for makerspaces. The study also taps into propositions for models that could stimulate interactions between actors in the maker movement.

IV. Research Findings and Analysis

Our findings are divided into five sections. First, we introduce the makerspaces we researched and explain the different makerspace models they follow. Second, we explore the types of innovation, learning, and skills development that we found occurring in each makerspace. Third, we discuss the IP and innovation ownership issues. Fourth, we share findings on the issue of innovation scalability in makerspaces. Fifth, we share the recommendations of the interviewees on how to measure the innovation that occurs in makerspaces.

A. Makerspaces Studied, and their Models

This section examines different components of each makerspace included in the study. These include the affiliation of the makerspace, how each space was created, the business model followed by each makerspace, and the extent of collaboration among makerspaces.

We found that the makerspaces we studied could be usefully broken down into three categories: (1) community-based makerspaces; (2) university-based makerspaces; and (3) private-sector-run makerspaces. We found that makerspaces in each of these three categories shared similar characteristics, challenges, and modes of operation. (The categorisation of some spaces as university-based or private-sector-run did not mean that these makerspaces lacked community ties. It meant that we found that reliance on the community was secondary for those spaces, with the university or the private sector company as the primary affiliation.)

Within the first category, community-based makerspaces, we identified two sub-categories: (a) those affiliated with and accredited by the Fab Foundation, meaning that they had to fulfill the requirements for tools and methods of operation set forth by the Fab Foundation; and (b) those that did not have any affiliation to the Fab Foundation, which thus were independent of any formal

organisation and largely dependent on their community. The second category, the university-based makerspaces, were those hosted and operated within a university campus. The third category, the private-sector-run makerspaces, were those directly affiliated with a private company, and reliant on company funding, but still maintaining community ties.

i. Makerspaces in Egypt

Makerspaces in Egypt are mainly concentrated in the capital city of Cairo. The cities of Alexandria, El Minya, Mansoura, and Assiut each host between one to four makerspaces. Table 1 below lists the makerspaces in Egypt as of November 2017. Not all the makerspaces in the table are included in this study. For those included, an overview is provided.

Aside from the makerspaces included in this study, other organisations in Egypt have continued to play an important role in gathering makers on a local level. These actors include universities and private and public stakeholders; together, they create a cycle of innovation that involves civic, educational, and corporate players, along with potential and actual entrepreneurial actors. Equipped with technological resources often not accessible elsewhere, these spaces provide an opportunity for makers to connect with formal entrepreneurial actors in the local ecosystem. Nevertheless, it would be desirable to see additional makerspaces emerging throughout a range of cities and localities to ensure that knowledge creation and sharing is not geographically concentrated. Government, civic, and private sector agents would be well served to realise the potential of makerspaces and their use as an innovative and sustainable means to leverage the creativity and entrepreneurial potential of their people.

Table 1: Makerspaces in Egypt

Makerspaces in Egypt

REGION	AFFILIATION	MAKERSPACE	WEBSITE
CAIRO	Fab Foundation	Fab Lab Egypt	http://fablabegypt.com/
	Fab Foundation	Fab Lab AUC	https://www.facebook.com/ FabLabAUC/
	Fab Foundation	Qafeer Makerspace	https://www.facebook.com/ qafeermakerspace/
	Fab Foundation	Fab Lab in New Cairo (FLiNC)	https://www.fablabs.io/ labs/fablabnewcairo
	Fab Foundation	Fab Lab 10th City	https://www.facebook.com/ FabLab10ThCity/
		HackZone	https://www.facebook.com/HackaZone/
		Cairo Hackerspace	https://www.facebook.com/ CairoHackerSpace/
		302 Labs	https://www.facebook.com/ 302Labs/
		Cairo-Dresden Interlabs	http://www.tandemforculture.org/collaborations/interlab-cairo-dresden/
		Kitchen Makerspace	https://www.facebook.com/ KitchenMakerSpace/
		Zone Makerspace	https://www.facebook.com/ ZoneEG/
	ICE Network	ICE Cairo (currently not operational)	http://www.icecairo.com/
ALEXANDRIA		Alex Hackerspace	https://www.facebook.com/ alexhackerspace/
		Karakeeb Makerspace	https://www.facebook.com/ karakeeb.co/
	ICE Network	ICE Alex	http://www.icealex.com/
	Fab Foundation	Future Production Engineering Organization	https://www.facebook.com/ ZoneEG/
MANSOURA	Fab Foundation	Fab Lab Mansoura	https://www.facebook.com/ FabLabMansoura/
		Circles Makerspace	https://www.facebook.com/CirclesMakerSpace/
EL-MINYA		El Minya Hackerspace	https://www.facebook.com/El-Minya-Hacker-Space-110235235753993/
ASSIUT	Fab Foundation	Assiut STEM Fab Lab	https://www.fablabs.io/labs/assiutstemfablab
ASWAN	Fab Foundation	Aswan Fab Lab (not operational yet)	https://www.facebook.com/FabLabAswan/

Fab Lab Egypt

After the 2011 Egyptian Revolution, in 2012 three passionate Egyptians established Fab Lab, operating out of a garage, to serve the local community. It was the first official Fab Lab and community-run makerspace to open in the country (Fab Lab Egypt, n.d.). The initial model was purely educational and focused on providing programmes and workshops. Fab Lab Egypt adopted the specs of the Fab Foundation. In 2016, Fab Lab Egypt moved to a new and larger location to become a platform for empowerment for other makers, to host startups, and to draw in individuals not involved in the maker movement. The space currently hosts three resident startups. The makerspace is founded on the principles of promoting innovation and education. It serves two main purposes: first, to provide an open collaborative makerspace equipped with digital fabrication and prototyping machines and tools; and second, to offer business-to-business (B2B) services that provide a source of revenue for the operation of the lab. Fab Lab Egypt also offers a six-week technical internship, called "Maker Chef" to educators and hackers specifically, and presents interns with an opportunity to join Fab Lab Egypt's tech team (Maker Chef, 2016).

Fab Lab Egypt has been self-funded since its inception. However, realising the need to supplement the self-funding, the model evolved so as to generate additional revenue, as well as to fulfill the goal of spreading the maker movement in Egypt. One way to do this was to involve businesses in the maker movement by offering them business-to-business (B2B) services. For instance, Fab Lab Egypt partnered with the Embassy of the United States (US) in Cairo and established a technology club within the embassy. Every Sunday, Fab Lab Egypt transforms the US embassy's Information Resource Center into a makerspace that offers an eight-week Mini-Maker Diploma. The key factor for Fab Lab Egypt in offering these B2B services was to find a balance between having a community-based makerspace that is affordable for makers while simultaneously scaling-up with an external source of revenue that does not affect the essence of the space (El Safty interview, 2017). The makerspace recently began directing their B2B work towards their main vision of spreading the maker culture by partnering with Orange Egypt, one of the largest mobile network operators, to create mini-Fab Labs in Egyptian governorates. Fab Lab Egypt is the caretaker of several other makerspaces throughout Egypt and also collaborates widely. Their rationale for collaboration is that they aim to spread the maker culture in the country, rather than monopolise the maker market.

The creation of Fab Lab Egypt was followed, in 2013, by the opening of Qafeer Makerspace in the 6th of October City district, and, in 2015, by the opening of Fab Lab in New Cairo (FLiNC), located in New Cairo. These makerspaces were intended to target citizens in both the west and the east of Cairo (Fab Lab IO, n.d.). When criticised by other emerging makerspaces in Egypt for having a "monopoly" on workshops offered to the community, Fab Lab Egypt suspended this service and began directing any workshop requests to other makerspaces in the country (El Safty interview, 2017). Fab Lab Egypt collaborates with other makerspaces in assisting new spaces to open up. Fab Lab Egypt also organises the annual Maker Faire Cairo, bringing together makers from different parts of Egypt to showcase their work and collaborate. For the smaller spaces unable to afford a booth at the Maker Faire, Fab Lab Egypt waives the fees to enhance the visibility of these smaller makerspaces in the maker community. Fab Lab Egypt has a strong belief that the closure of any makerspace has a negative impact on the maker movement in Egypt as a whole.

Qafeer Makerspace[1]

Affiliated with the Fab Foundation, Qafeer Makerspace functions mainly as a community-run makerspace. It aims to attract those with pre-existing knowledge of making, due to the limited number of staff available to offer assistance to pre-makers. Qafeer Makerspace emerged in 2013 by utilising the meeting room of an existing co-working space, Qafeer Labs. The founders of the co-working space started an online crowd-funding campaign on Zoomal,[2] managing to raise US$16,730 to establish the makerspace. Qafeer Makerspace was the first space established in the 6th of October district. It collaborates with other makerspaces in utilising tools that they do not have, in addition to attending the various maker events held in Egypt, depending on admission costs (El Zoughby interview, 2017). Qafeer rents out a space to patrons, and although it is open to everyone, Qafeer offers few formal sessions on using the available maker tools, and rather relies on attracting more experienced makers (El Zoughby interview, 2017).

[1] After we conducted our interview, we learned that Qafeer Makerspace had ceased operations due to difficulties faced in financially sustaining the space.
[2] http://www.zoomaal.com

Fab Lab in New Cairo (FLiNC)

FLiNC was launched in late 2015 by Giza Systems, with the help of Fab Lab Egypt. It is located within the offices of Giza Systems, a systems integrator in the Middle East and North Africa, which assists businesses in asset-intensive industries streamline their operations. FLiNC is fully funded by the private sector, specifically Giza Systems and EMC2 Dell, as part of the corporate social responsibility (CSR) programmes of both entities, thereby operating as a community-based makerspace with corporate funding. Being associated with a private company brings advantages in terms of finding financial resources to create the space (El Raffei interview, 2017). FLiNC is accredited by the global Fab Foundation and aims to provide an inspiring space for pre-makers as well as pro-makers. It is registered as a non-governmental organisation (NGO), under the Giza Foundation umbrella, and although it is located on the premises of a private company, FLiNC aims to serve the maker community at large and to expand its maker base. It offers regular workshops to the maker community in Egypt.

It collaborates with other spaces in competitions and events. For example, together with Fab Lab Egypt, FLiNC co-hosts Fab Lab on Wheels (FLoW), a mobile Fab Lab created to improve accessibility to those without the financial means to pay for a makerspace, or those in rural areas outside the geographic reach of stationary makerspace locations. FLoW is located inside a movable bus and has the typical tools and devices that most makerspaces have, such as a laser cutter, 3D printer, and computer numerical control (CNC) router. The bus mostly tours governorates outside of Cairo and Alexandria where virtually no makerspaces exist. Volunteers help makers use the tools provided in the space, and also discuss the viability of potential products makers want to create (Fab Lab on Wheels, n.d.).

Fab Lab AUC

Located at the American University in Cairo (AUC), Fab Lab AUC officially began operating in April 2017 for AUC students (News@AUC, 2017). Two engineering students at AUC launched Fab Lab AUC, and it is the only university-based makerspace in Egypt that is included in this research. AbdelRahman Shalaby, one of the co-founders of Fab Lab AUC, was first introduced to the concept of a makerspace when he interned at Fab Lab Egypt. He wanted to bring this concept to AUC students, so he partnered with another student, Mohamed Ragab, to create the space. Fab Lab AUC was built from scratch in an existing lab at AUC's New Cairo Campus. Shalaby and Ragab pitched the idea to the Mechanical Engineering Department, and received moral encouragement but no financial support. They then turned to different entities on campus to solicit the necessary funds to open the makerspace (Shalaby and Ragab interview, 2017). It now receives financial support from various university entities, such as the Mechanical Engineering Association at AUC (Shalaby and Ragab interview, 2017).

Fab Lab AUC is a rapid prototyping working space, currently equipped with three machines: a 3D printer, a laser cutter, and a four-axis CNC milling machine, along with a variety of other mechanical and electronic tools. It follows the global Fab Lab model and therefore requires a certain set of machines to be accredited by the Fab Foundation as a fully functioning Fab Lab. It currently needs two more machines to fulfill the requirements for this accreditation.

Fab Lab AUC is a non-profit entity, and while it charges a symbolic fee for the use of the space, all money is poured back into the lab and used to buy materials and to support projects. Fab Lab AUC

has made a conscious choice to remain independent and not collaborate with other makerspaces until they have established a name for themselves.

Karakeeb Makerspace

Located in the coastal city of Alexandria, community-based Karakeeb Makerspace, was established in 2013. Karakeeb Makerspace is a mini-makerspace that attempts to spread technology and knowledge of digital fabrication, as well as the culture of making to people with a non-engineering background. Karakeeb Makerspace was created in the previous storage space of the French library of the Jesuit Cultural Center in Alexandria. The space is completely volunteer-based and self-funded; it also relies on non-financial donations in the form of machines and tools.

Karakeeb Makerspace collaborates closely with Fab Lab Egypt and ICE Alex, a second makerspace in Alexandria, and participates in Egypt's annual Maker Faire in Cairo. Karakeeb Makerspace was founded as a result of a partnership between two Egyptian youths and a pastor. The pastor first provided Mina Effat and Rabab Hassan with a 2x2 metre room to set up the makerspace in the Jesuit Cultural Center in Alexandria. A few months later, a slightly bigger room, 2x5 metres, became available and Karakeeb's co-founders began to search for funds. They received the money for their first machine from a friend of the pastor, who asked his wedding guests to give gifts in the form of monetary contribution to Karakeeb (Effat and Hassan interview, 2017). Karakeeb aims to support startups and works with local NGOs to spread the maker culture, especially targeting underprivileged youth. The space maintains close ties to the Egyptian maker community through participation in events and workshops.

ICE Alex

ICE (Innovation, Collaboration and Entrepreneurship) Alex is another makerspace in Alexandria, and is part of the international ICE hubs network based in Germany (with branches in Ethiopia, Egypt, and Germany). The ICE hubs focus on helping developing countries create environmentally friendly and sustainable products. The makerspace was built in 2013 by three youths in Alexandria with the help of the maker community and a crowd-funding project. The space was formed gradually over about three years using combined efforts, including the time and resources of the community and various partners.

ICE Alex encourages an open source collaborative culture. The space also holds monthly workshops to transfer various technical skills to makers, in addition to an entrepreneurship programme to help interested makers develop their innovation and become more market-driven. There is a co-working area within the space, as a secondary activity to the makerspace. ICE Alex aims to have a steady source of income from corporate users to subsidise services for startups and students (Bastawy interview, 2017). It is a proponent of collaboration between different makerspaces in the Egyptian maker scene and encourages the sharing of advice on the operation of various makerspaces. ICE Alex also participates in the annual Cairo Maker Faire. In January 2017, their sister branch, ICE Cairo, shut down due to the rising costs of products necessary for the operation of the makerspace and the increasing economic challenges in Egypt generally (ICE Cairo, 2017).

Alex Hackerspace

The third makerspace in the city of Alexandria is Alex Hackerspace, a community-run makerspace established in 2015 solely using self-funding. Amr El Shaer came up with the idea for Alex Hackerspace in 2010, but it was not until 2015 that he co-founded it with his partner. In 2014, El Shaer was awarded a place in the US Department of State's International Visitor Leadership programme, a professional exchange programme that allowed him to tour the US for 22 days, examining different makerspace models. Upon his return, El Shaer quit his full-time job and focused on creating Alex Hackerspace in Egypt's city of Alexandria (El Shaer interview, 2017).

Alex Hackerspace provides a variety of tools for makers at a low cost, as well as consultancy services and courses on hands-on creation of different innovations and products. The space is completely self-financed by its founders, both in terms of machinery and operational costs. Alex Hackerspace caters both to makers with an engineering background, as well as to makers new to the idea of fabrication and hands-on innovation. They maintain close ties to the Egyptian maker community through co-hosting workshops and participating in events.

Table 2 below summarises the findings from the questions about the makerspace models for the spaces interviewed in Egypt.

Table 2: Makerspace Models in Egypt

Name of makerspace	**Year of establishment**	**Makerspace model**	**The actual "space"** (new vs. upgraded spaces)	**Funding source**	**Charges for space and machine use**	**Collaboration with other makerspaces**
Fab Lab Egypt	2012	Community-based Co-working space	Original location: Upgraded from personal garage New location: New space	Self-funding	Yes	Yes
Qafeer Makerspace	2013	Community-based Co-working space	Upgraded within existing co-working space	Crowd-funding and self-funding	Yes	Yes, to a certain extent
Fab Lab in New Cairo (FLiNC)	2015	Community-based	Upgraded within an existing private company	Private funding	Yes	Yes
Fab Lab AUC	2017	University-based	Upgraded from empty lab space at AUC	University funding	Yes	None
Karakeeb Makerspace	2013	Community-based	Upgraded space within cultural centre	Crowd-funding and self-funding	Yes	Yes
ICE Alex icenetwork	2013	Community-based	New	Self-funding	Yes	Yes
Alex Hackerspace	2015	Community-based	New	Self-funding	Yes	Yes

The maker movement in Egypt has been on the rise since 2012. Most makerspaces are concentrated in the major cities of Cairo and Alexandria, as seen in Table 1 earlier. There has been a recent attempt, however, to spread the maker culture through the creation of mini-makerspaces in different governorates. Nevertheless, the sustainability of these initiatives remains questionable. A strong sense of ties to the community characterises all of the makerspaces in Egypt that participated in this research, with the exception of Fab Lab AUC, which chooses to operate independently for the time being.

With the exception of ICE Alex and Alex Hackerspace, the rest of the makerspaces are located in spaces that previously existed for other uses. Upgrading an existing space into a makerspace enables the spaces to efficiently utilise their resources. FLiNC is the only makerspace in this research that relies on private funding for its operations, and stands out as the only space in this study for which funding is not a major concern. The others rely on self-funding, and a few have resorted to crowd-funding. The source of funding for makerspaces is a major challenge. All the makerspaces in this research levy charges on the use of the space and the machines.

In Egypt, makerspaces find significant challenges with licensing and registration. Any makerspace not hosted within an already licensed entity—e.g., a university, private company or other entity—has to register itself as a business in order to operate legally in Egypt. This registration is a requirement by Egypt's Ministry of Investment and International Cooperation for starting any type of business. Officially, there is no specific categorisation for the registration of makerspaces, which is problematic. One makerspace is registered as an "Internet café", while another is registered as an NGO. Facilitating the registration and licensing of makerspaces as special spaces for rapid prototyping services would be advantageous, as would state intervention to allow tools and equipment to be imported more efficiently and with lower customs tariffs.

ii. Makerspaces in Tunisia

In Tunisia, makerspaces are concentrated in the capital city, Tunis. Compared to Egypt, there is less widespread affiliation with the Fab Foundation for the makerspaces in Tunisia. Table 3 below lists the identified makerspaces in Tunisia. We were only able to reach two of them for this study. An overview of those interviewed is presented below.

Table 3: Makerspaces in Tunisia

Makerspaces in Tunisia

REGION	AFFILIATION	MAKERSPACE	WEBSITE
TUNIS	Fab Foundation	Fab Lab Solidaire	https://www.fablabs.io/ labs/solidaire
	National Engineering School of Tunis	Fab Lab ENIT	https://www.fablabs.io/ labs/fablabenit
		Level 1 Tunisia	https://www.facebook.com/pg/ Level1Hub/about/?ref=page_internal
		Hackerspace Tunisia	http://hackerspace.tn/index.php/ Accueil
LA MARSA		El Fab Lab	https://www.fablabs.io/ labs/elfablab

Fab Lab ENIT

Fab Lab ENIT is one of the few makerspaces in North Africa situated in a university. The space was set up within the National Engineering School of Tunis in 2013 by a professor as a collaboration initiative with other professors from Europe to bring innovation modules to universities across North Africa. The goal of the makerspace is to give students and faculty equal access to different modes of production. Fab Lab ENIT is unique among other makerspaces in Tunisia and North Africa, as it does

not charge any subscription fee for using the space. This removes any financial barriers to using the space, although users pay for the costs of the materials they use. The space is student-run and is the first Fab Lab in Tunisia to be accredited by the Fab Foundation. When first established, Fab Lab ENIT was funded by the European Union (EU) as part of an ongoing collaboration between ENIT and the EU, and now the space is fully funded by the university. Fab Lab ENIT collaborates with other makerspaces in Tunisia, as well as several Fab Labs throughout Europe (Ben Rejeb interview, 2017). The space relies on the university to give students formal training in engineering production, in contrast to most other spaces that give workshops and informal one-on-one sessions.

Level 1 Tunisia

Level 1 Tunisia was the other makerspace that we managed to reach for this study. Established in September 2017 in the city of Tunis, it is both a makerspace and a co-working space. It focuses on helping makers in the gaming and video industry, specifically on 3D gaming, Virtual Reality (VR) and Augmented Reality (AR)—areas the founders believe have not been tackled by the maker movement in Tunisia. Level 1's main aims are to enhance the culture of making in the areas of visuals, gaming and video, and to help makers gain access to these industries. The space also provides VR and AR workshops for adults and students in the community, as well as workshops for children to help them create their own applications and games (Bouslama interview, 2017). Level 1 is completely self-financed by one of the partners, who uses revenue from his amusement park company, Carthage Land, to sustain the space and purchase the necessary tools.

iii. Makerspaces in Morocco

There are fewer makerspaces in Morocco when compared to Egypt, although they are generally more geographically spread out than makerspaces both in Egypt and Tunisia. Most of the identified makerspaces in Morocco are associated with the Fab Foundation. The makerspaces identified are listed in Table 4 below. We were only able to reach Fab Lab Casablanca for this study.

Table 4: Makerspaces in Morocco

Makerspaces in Morocco

REGION	AFFILIATION	MAKERSPACE	WEBSITE
CASABLANCA	Fab Foundation	Fab Lab Casablanca	https://www.fablabs.io/labs/fablabcasablanca
	Fab Foundation	Casanostra	https://www.fablabs.io/labs/casanostra
		Open Taqafa	https://www.facebook.com/pg/opentaqafa.cc/about
BENI MELLAL	Fab Foundation	Fab Lab USMS	https://www.fablabs.io/labs/fablabusms
SIDI KACEM		Had Kourt Lab	https://www.facebook.com/hadkourtlab/
TANGIER	Fab Foundation	Fab Lab Tanger	http://fablabtanger.ma/
TARFAYA		Sahara Labs	http://www.tandemforculture.org/collaborations/interlab-cairo-dresden/
TEMARA	Fab Foundation	Fab Lab Temara	http://www.icecairo.com/
TEMARA		SMARTiLab	https://www.facebook.com/ 302Labs/

Fab Lab Casablanca

Fab Lab Casablanca was launched in 2014 after two makers attended a Fab Foundation event in Munich, Germany and were inspired to replicate the Fab Lab model in their hometown of Casablanca.

Fab Lab Casablanca is fully accredited by the Fab Foundation and emphasises a self-manufacturing, do-it-yourself (DIY) culture, using computer-controlled machinery. The space is open to anyone who wants to use the tools and equipment for educational, commercial, or personal interests. The machines include laser cutters, a 3D printer, and various electronic tools. The space also offers measuring tools and Plexiglas plates to enable makers to create a variety of objects. In addition to these machines, Fab Lab Casablanca offers workshop spaces, provides several courses and workshops on how to use specific machines, as well as workshops on concept design and basic making concepts for beginner makers. The space welcomes pro-makers as well as pre-makers (Fab Lab Casablanca, n.d.). Fab Lab Casablanca is completely self-funded by one of its founders, based on revenues from a private computer chip company. Fab Lab Casablanca has strong ties within the maker community and provides free weekly training sessions. It also has an association for entrepreneurs that encourages makers to scale their creations into businesses (Abouch and Kouska interview, 2017).

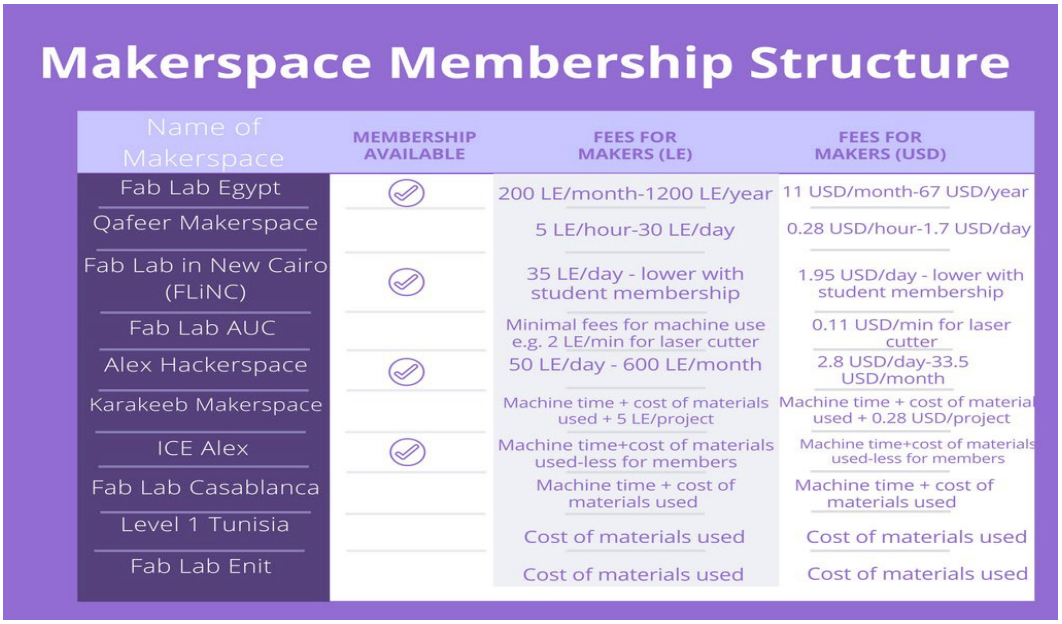
Table 5 below summarises the findings from the questions about the makerspace models for the spaces interviewed in Tunisia and Morocco. Unlike Egypt's university-based makerspace Fab Lab AUC, Fab Lab ENIT does collaborate with other makerspaces. The three makerspaces charge for the use of their space and machines.

Table 5: Makerspace Models: Tunisia and Morocco

Name of makerspace	**Year of Establishment**	**Makerspace model**	**The actual "space"** (new v. upgraded spaces)	**Funding source**	**Charges for space and machine use**	**Collaboration with other makerspaces**
Fab Lab ENIT	2013	University-based	Built from scratch within university campus	Private funding and university funding	Yes	Yes
Level 1 Tunisia	2017	Community-based	New	Self-funding	Yes	Not yet
Fab Lab Casablanca	2014	Community-based	New	Self-funding	Yes	Yes

Key to enquiring about makerspace models in Egypt, Tunisia, and Morocco was asking about their membership structure. Membership structures varied from monthly memberships to hourly rates, and the fees charged were all nominal fees to ensure the survival of the makerspaces. These results are presented in Table 6 below.

Table 6: Makerspace Membership Structure



Makerspace Membership Structure

Name of Makerspace	MEMBERSHIP AVAILABLE	FEES FOR MAKERS (LE)	FEES FOR MAKERS (USD)
Fab Lab Egypt	✓	200 LE/month-1200 LE/year	11 USD/month-67 USD/year
Qafeer Makerspace		5 LE/hour-30 LE/day	0.28 USD/hour-1.7 USD/day
Fab Lab in New Cairo (FLiNC)	✓	35 LE/day - lower with student membership	1.95 USD/day - lower with student membership
Fab Lab AUC		Minimal fees for machine use e.g. 2 LE/min for laser cutter	0.11 USD/min for laser cutter
Alex Hackerspace	✓	50 LE/day - 600 LE/month	2.8 USD/day-33.5 USD/month
Karakeeb Makerspace		Machine time + cost of materials used + 5 LE/project	Machine time + cost of material used + 0.28 USD/project
ICE Alex	✓	Machine time+cost of materials used-less for members	Machine time+cost of materials used-less for members
Fab Lab Casablanca		Machine time + cost of materials used	Machine time + cost of materials used
Level 1 Tunisia		Cost of materials used	Cost of materials used
Fab Lab Enit		Cost of materials used	Cost of materials used

It was found that all the spaces levied an entry fee of some sort, whether in the form of a membership or an hourly rate. Four out of the 10 makerspaces in the study had a membership structure in place; the remaining six spaces charged per hour or per day, or according to the costs of the materials used. Financial remuneration did not seem to be a motivating factor for the operations of any of the makerspaces. This is in line with the openness of the maker culture, whereby alternative sources of finance are sought for the sustainability of the spaces without placing the financial burden on the makers themselves. Nevertheless, this results in challenges. Lack of or inadequate funding was cited by most makerspace founders interviewed as their major challenge. Rent costs and space issues were also cited as challenges. Despite these financial constraints, the makerspaces all sought sources of revenue independent of the fees they charge makers, to avoid creating barriers to access to the spaces.

B. Innovation, Learning, and Skills Development

The next set of questions sought to understand how the makerspaces acted as conduits of different types of innovation, learning, and skills. Key to this was asking about the types of innovation and learning environment most prevalent in the makerspaces. In order to understand if, and the extent to which, makerspaces affect entrepreneurship, we asked if makers learned any skills that helped them find employment later on.

i. Innovation

Due to the nascent nature of the maker movement in the countries studied, problems to which solutions were sought in makerspaces covered a wide range: everything from wanting a cheaper version of fidget-spinners to creating artificial limbs. As exemplified in the anecdotes presented below, makers mainly sought low-cost innovative solutions to individual or societal problems. We found three exceptions to this phenomenon. The first was makerspaces used by students for educational purposes, such as fulfilling course requirements or assignments. For instance, the regular makers at Qafeer Makerspace were students, producing small-scale projects and innovations

required for their university courses. Use mainly for educational purposes was also the case for Fab Lab AUC and Fab Lab ENIT. The second exception were recently established makerspaces that were trying to spread the maker culture to the general public and to individuals with no engineering background. The third exception were makerspaces with a specialised focus, such as Level 1 Tunisia, which specifically targeted makers interested in gaming, AR, and VR.

The type of innovation that was found to be most prevalent in Fab Lab Egypt was the generation of innovative, low-cost solutions to local problems. For example one maker created a low-cost artificial limb. This was undertaken as a personal project to address a larger societal problem to which few low-cost solutions exist. Makers at ICE Alex also sought lower-cost innovative solutions to daily problems as well. One example was a portable laser cutter, called Reesha Portable Laser Cutter, and its supplementary mobile application, which allows users to draw directly on their phones and to laser-cut the drawing. This is aimed at supporting marginalised communities with no access to this technology; it is also quite difficult to transport a full-sized laser cutter to these communities (Bastawy interview, 2017). Another example was that of a water purification filter that uses palm tree branches and stones, which was developed by a girl whose parent suffered from kidney problems due to contaminated water. This locally relevant low-cost alternative works almost as well as the expensive industrialised version (Bastawy interview, 2017). The types of innovations taking place at ICE Alex were found to be for the purposes of learning and discovery, or for solution-based purposes. Innovations varied across hardware, digital, mobile applications, and low-tech inventions.

It was found that FLiNC aims to promote systematic innovation, breaking down the process of creating, and having an end goal. People who visit FLiNC usually access the space with an idea for their creation already in mind, and the space mainly produces low-budget products in the forms of picture puzzles and woodworks. Fab Lab AUC was also found to be among the makerspaces where low-cost innovations are being developed, with students being the makers. For example, fidget-spinners were created at Fab Lab AUC for less than half their market price (Shalaby and Ragab interview, 2017). Alex Hackerspace also seeks to provide an environment for the development of low-cost innovative solutions. At Karakeeb, it was found that innovation usually occurs when makers set out to create solutions either to a problem in their everyday lives, or to ones they witness in their community. Projects at Fab Lab ENIT were found to be usually centred on 3D-printing (Ben Rejeb interview, 2017). Recently, for example, a maker at the space had created a robotic hand using 3D printing. At Fab Lab Casablanca, the most common areas of innovation were found to be in technology, electronics, and 3D printing.

ii. Learning

We found that both formal and informal learning occur in the makerspaces and, most importantly, all the learning that takes place is voluntary. Even amongst the structured learning that takes place, for example in the form of workshops or training sessions, individuals join voluntarily to gain knowledge. Informal modes of learning, in line with the community of practice ethos (Sheridan et al., 2014) mentioned earlier, were found to be prevalent in all makerspaces in the study. Peer-to-peer collaboration among users of the spaces was found to be key to the spaces' community-of-practice attributes. Formal internships were found to be another mechanism used, in some of the makerspaces, as a learning tool.

Fab Lab Egypt's makerspace model highly depends on a culture of learning. They offer customised programmes in the form of B2B services and programmes for science, technology, engineering, and mathematics (STEM) schools. Fab Lab Egypt also offers the Maker Diploma, which introduces the basic principles of making and prototyping. Additionally, Fab Lab Egypt is the pioneer in spreading awareness and knowledge about the maker culture in Egypt.

FLiNC aims to adopt an innovative learning process (El Raffei interview, 2017). In order to do this, learning is aimed at non-technical audiences who are not engineers; they teach engineering methodologies and sequential thinking. Workshops at FLiNC break down big projects into small parts, all of which eventually fit together. Their main focus is teaching engineering learning strategies to transform pre-makers into pro-makers. Therefore, conceptual design is important, as it relates to how people can think of a design for something to be produced. Makers are also introduced to the limitations of each machine (El Raffei interview, 2017). In addition, FLiNC provides process management workshops that people can add to their resumes.

Fab Lab AUC stresses learning by doing and designing for manufacturing. The users of Fab Lab AUC are mostly engineering students, and the space aims to bridge the gap between a design idea, and actual implementation and manufacturing. The Fab Lab AUC team is trained to use the machines so that they can assist makers who visit the space. Fab Lab AUC offers entrepreneurs the space to create a prototype of their idea. This was found to be more useful than offering entrepreneurs of a manufactured product a service, as they need a prototype to show investors. Fab Lab AUC also has a technical team to help entrepreneurs without a background in design. Because they only recently launched, there are no documented cases of employment generation as a result of the skills acquired in the makerspace (Shalaby and Ragab interview, 2017).

At Alex Hackerspace, makers are exposed to "unconventional learning", whereby tools are used to create new products (El Shaer interview, 2017). This type of learning and skill exposure is unique to makerspaces and not prevalent in the formal educational curriculum. Alex Hackerspace offers courses in woodworking, metal welding, 3D printing, laser cutting, using CNC routers and other electronics, in addition to creating handicrafts. Makers work and learn within groups in a collaborative environment, gaining skills through trainings that are offered, which is often cited on their resumes to help them in finding employment.

Different types of learning occur at Karakeeb Makerspace, not only in the form of mentoring but largely as a result of peer-to-peer experiences. Karakeeb offers an introductory safety and electronics course for anyone who visits the space for more than three hours. Karakeeb staff also provide help in operating the machinery. Furthermore, the learning that occurs at Karakeeb transpires organically as a result of collaboration. Collaboration was described as being highly prevalent in the space, with the co-founders stating that people from different disciplines work better together and learn from each other (Effat and Hassan interview, 2017). The trend towards collaboration and away from competitiveness can be partially attributed to the fact that Karakeeb is based in a cultural centre.

ICE Alex teaches the do-it-yourself (DIY) concept, exploring and learning by trial and error, while at the same time encouraging peer-to-peer mentoring. ICE Alex hosts monthly workshops targeting different skill sets for makers, in addition to offering entrepreneurship programmes for makers and artisans. Mentoring and technical assistance sessions are offered on different occasions. Additionally,

ICE Alex organises and hosts networking events and hackathons to generate ideas relevant to communal and societal problems.

One-on-one assistance is the main learning tool offered at Qafeer Makerspace, whereby the makerspace staff help students while they work on their projects. For example, one co-founder is the go-to-person for learning about product design. Qafeer also offers courses, which take up to 15 people, based on the demand for a certain topic. Due to time and resource constraints, Qafeer staff usually operate the 3D printer and other tools for the students. Therefore, although the students are introduced to the tools available in the space and learn how they function, they do not usually focus on how to operate them on their own (El Zoughby interview, 2017).

At Fab Lab ENIT, makers, who are almost exclusively students at the university, often learn valuable skills by watching the innovation process of each other's projects. In addition, Fab Lab ENIT holds regular training sessions. At the Level 1 makerspace, workshops for adult makers are provided in the areas of AR and VR. There are also workshops for children, called Kids Hacker Labs, to enhance children's coding, software, and application building skills (Bouslama interview, 2017). In general, the space caters to students, including Masters and PhD students who are looking for access to tools to complete their graduation projects. Makers at Level 1 have access both to the regular space, as well as a "VIP" option of using Level 1's co-working space, which has the additional benefit of providing a few select makers with consultancy services, in return for producing a creation that benefits the community.

Makers who frequent Fab Lab Casablanca can learn more about technology, electronics, and 3D printing by attending the free weekly training sessions conducted by volunteers. Session topics are based on the preferences of makerspace users to ensure that Fab Lab Casablanca provides a useful platform for learning. Makers learn useful skills from these workshops, as well as from makerspace staff.

iii. Skills Development

Structured and unstructured learning leads to skills development, which occurs in all makerspaces. There were varying degrees of skills development in the makerspaces in this study. Most offered targeted workshops and trainings aimed at improving the personal skills of makers. Although in our interviews we did not find any direct correlation between skills development and finding jobs, with the exception of one female from Karakeeb Makerspace, the lack of direct correlation should not undermine the importance of the skills development that takes place and the impact on entrepreneurship. Introducing individuals to new skill sets contributes to their capacity development, which in itself is an important entrepreneurial asset. Makerspaces provide an arena in which youth can learn new skills and develop an entrepreneurial mindset. Additionally, the maker movement across North Africa is still relatively young, and it takes time to develop and nurture a maker culture that can yield sustainable sources of employment.

For example, one female maker started an accessory and decoration business based on products she designs and creates at Karakeeb Makerspace. The makerspace provided her with the design and implementation skills needed for her business, in addition to affordable access to machinery. A few years ago, makers at Karakeeb created an emergency lamp, powered by old mobile phones to address Egypt's power cuts. This was a low-cost solution to a societal problem, and is an example of

an entrepreneurial endeavour. In an environmental effort, Karakeeb co-founders and makers collaborated to create a trash bin that rewards the user for correctly separating trash, by posting to social media and praising your environmental effort (Effat and Hassan interview, 2017). This also can translate to a new business opportunity.

Fab Lab Egypt's El Safty (interview, 2017) explained that makers learn skills that help them in their daily jobs. For example, a dentist who was awarded his Maker Diploma from Fab Lab Egypt began printing 3D molds in order to improve the accuracy of his procedures during operations. Fab Lab Egypt is currently setting up an online platform to document and track success stories of makers in Egypt. The aim is to provide makers with more exposure and opportunities by providing a medium on which they can exhibit their innovations to a wider audience.

ICE Alex has the advantage of having a makerspace situated within a larger technology innovation space, thereby equipping makers with entrepreneurial skills to direct their products to markets. The space also offers a three-month internship, whereby interns experience different staff roles, which include becoming part of the makerspace team. The internship works on developing the different skills of individuals.

Students at Qafeer Makerspace spend the majority of their time learning about design skills, as opposed to how to use the tools in the makerspace. Because most of these makers are students, these skills are likely to benefit them as they join the workforce. At Fab Lab ENIT, makers, who are almost exclusively students at the university, learn from their community of practice. The directors of Fab Lab Casablanca stressed that people work more in groups than individually, and learn an abundance of skills from each other (Abouch and Kouska interview, 2017). They explained that at Fab Lab ENIT makers have access to machines that are difficult and expensive to access. At the space, they can access the machines easily and at a low cost, and can use the knowledge and skill sets gained in their later employment.

Fab Lab ENIT also holds regular training sessions on concept creation, design, digital manufacturing, and 3D printing, in which new makers learn the necessary skills from teachers or mentors. These skills have helped makers secure employment after graduation. Several makers have utilised these skills to obtain internships and job opportunities. Makers report that job interviewers are very interested in the innovations they have created at the Fab Lab (Ben Rejeb interview, 2017). Level 1's Bouslama (interview, 2017) explained that the software skills needed to enter the gaming market that are obtained through use of the regular and co-working space, as well as via attendance at various workshops, helps young entrepreneurs find employment in the gaming market—a market driven by young entrepreneurs.

C. Innovation Ownership, Formalised Intellectual Property (IP) Protection, and Collaboration

This third section of findings covers our attempt to explore the extent to which elements of innovation ownership, intellectual property (IP), and approaches to collaboration shape and affect the innovation processes at the makerspaces studied. We made enquiries about innovation-ownership disputes and how they were resolved, as well as about the rules that govern the relationship between the makerspaces and makers. We also sought to understand if the makers were

more inclined towards (1) openness-based approaches, or (2) proprietary approaches, to their innovations and the potential IP rights flowing from those innovations, and the degree to which a collaborative innovation environment prevailed in their spaces.

We found was that there were indeed innovation-ownership disputes arising in the makerspaces, but that the disputes did not tend to have a formal-IP-rights dimension. And we found that while the maker culture is based on notions of open source and a culture of sharing, there was sometimes a degree of discrepancy between theory and reality when it came to the actual behaviours of makers in respect of innovation ownership and collaboration.

i. Innovation Ownership

The topic of innovation ownership is important to examine in the informal-innovation context of makerspaces. While makerspaces promote an openness ethos, our interviews found that the makers sometimes had a different sentiment. Founders of the makerspaces studied stated that makers were often wary of sharing their ideas for fear of copying, despite the open and collaborative environment that the makerspaces offer. This, however, was not the case in any of the makerspaces in which students were the users, and in which the end result was an academic project.

We found that three of the makerspaces in the study—Alex Hackerspace, ICE Alex, and Fab Lab Egypt—had structures for dealing with innovation-ownership issues inside the spaces. At Alex Hackerspace, the makers, before working on any group project, had to sign an agreement outlining the division of roles and percentage of work on each task in the project, so that everyone knew which part was assigned to them and what their share was in the final outcomes (El Shaer interview, 2017). This signed agreement was used to settle ownership disputes. (In our analysis, whiles structures such as this would seem to be potentially important and useful during a dispute, it is debatable how accurate pre-determined percentages of work can be, particularly given the highly collaborative nature of making.)

At ICE Alex, mediation, facilitated by the space, was seen as the way in which innovation-ownership disputes could be settled. In an effort to prevent disputes from arising in the first place, ICE Alex hosted regular workshops on the elements of the open source culture (Bastawy interview, 2017).

At Fab Lab Egypt, innovation-ownership disputes were resolved through reaching of an agreement that gave a single person ownership or that provided for shared ownership. These disputes were resolved among the makers themselves, with Fab Lab Egypt facilitating the reaching of an agreement but remaining neutral (El Safty interview, 2017). It was found that innovation-ownership disputes typically arose when a maker felt a product might be marketable. El Safty (interview, 2017) was not able to provide information on the frequency of such disputes.

It was also found that Fab Lab Egypt would only directly intervene in a dispute between members of the community if the dispute was seen as affecting the reputation of the space or the maker community as a whole. The space would also intervene where the dispute involved one of its staff members (El Safty interview, 2017). It was found that Fab Lab Egypt did not have a formal code of conduct—an absence which, according to the space's general manager, was problematic, i.e., it was problematic to have a shared culture but no written rules governing it. (However, in our analysis, the

culture encourages giving credit where it is due, and mutual cooperation and respect—elements which do not require a code of conduct.)

At FLiNC, we found that there had been some innovation-ownership disputes, between makers, which were never resolved because, according to El Raffei (interview, 2017), there was no formal dispute settlement mechanism in place. El Raffei stated that FLiNC could benefit from having a guide on how to establish formal IP rights in one's innovation, so as to provide clarity and limit the chances for ownership issues to arise during the informal-innovation phase (interview, 2017).

At Qafeer Makerspace, it was found that innovation-ownership disputes were almost non-existent, due to the small size of the group of makers and the nature of their outputs (El Zoughby interview, 2017). At Karakeeb, there had not yet been any innovation-ownership disputes and, accordingly, the space was not playing a role in monitoring ownership issues. There had also not been any innovation-ownership disputes at Fab Lab AUC, mainly because the outputs of the makerspace had been prototypes and not products (Shalaby and Ragab interview, 2017). Similarly, we found that there had not been any innovation-ownership disputes at Fab Lab ENIT, and the makerspace director explained that so far makers have been willingly sharing their work and models, and thus there has been no need for ENIT staff to monitor ownership issues (Ben Rejeb interview, 2017). At Fab Lab Casablanca, the space stated that the creator of a project had full ownership over it and the only role the Fab Lab played was in helping makers create a prototype by providing access to specific machines. Given that Level 1 Tunisia had only launched very recently at the time of our research, the space had yet to see whether issues of innovation ownership would arise among makers in the space (Bouslama interview, 2017).

Table 7 below summarises the findings on the degree to which the makerspaces in the study had structures in place for dealing with innovation-ownership issues. In our analysis, because innovation-ownership disputes do arise, it is important for makerspaces to have a structure in place for settling the disputes.

Table 7: Makerspaces and Innovation-Ownership Dispute Structures

Does the makerspace have a structure for dealing with ownership disputes?			
	Yes	**No**	**Explanation**
Fab Lab Egypt	✓		The space remains neutral in such disputes, but plays a role in facilitating reaching an agreement of some sort.
Qafeer Makerspace		✓	The space is more concerned with introducing skills and augmenting university education, rather than creating new inventions, so they have not faced the need for such a structure.
Fab Lab in New Cairo (FLiNC)		✓	Currently there is no system, but they are looking at changing this.
Fab Lab AUC		✓	Until now, the space has only been used by students for their courses, and thus there have not been concerns about ownership, so there is no need for such a structure.
Alex Hackerspace	✓		The space requires makers to sign a written agreement on the division of roles in each project, so everyone knows which part is assigned to them and what their share is in the final outcome.
Karakeeb Makerspace		✓	No monitoring because no conflict of ownership has occurred.
ICE Alex	✓		The space tries to raise awareness of the open source culture, and mediation meetings are used to address ownership issues.
Fab Lab Casablanca		✓	The space does not view this as part of its mandate; it views its role as helping makers create their prototype and providing access to specific machines.
Level 1 Tunisia		✓	The space leaves issues of ownership to the makers and does not monitor the innovation process.
Fab Lab ENIT		✓	While they consider the creator of the project as its owner, they do not necessarily have a structure to monitor the process because they encourage working on open source models and so far makers have been happy to do so.

ii. Formalised Intellectual Property (IP) Protection

We found that considerations of formal IP protection were having little influence on the innovation processes taking place in the makerspaces studied. Although competition was cited by most of the interviewees as a deterrent, to some extent, to collaboration, there was little concern expressed about instituting possible formal IP protection measures.

We did learn, from our interviews, that some users in makerspaces feared that other users would copy their ideas and resulting products, due to the open nature of the makerspaces, but they did not express this fear in terms of the possibility of formalised IP protection. The reasons for this lack of focus on formal IP were, in our analysis, twofold and related. First, the users of the makerspaces interviewed tended to be what can be referred to as "pre-makers"—individuals at a very early stage

of joining the maker movement, who are still seeking knowledge about self-manufacturing tools (see earlier explanation). Second, the makerspace managers stated that the types of innovations taking place did not tend to warrant consideration of formalised IP protection. Since pre-makers are new to the maker movement, the innovations that they produce do not tend to be really new products that could qualify for formal IP protection. Additionally, makerspace managers explained, the issue of formal IP was ambiguous to most of the users, with some exceptions.

Omar El Safty, the general manager of Fab Lab Egypt, explained that the physical setup of makerspaces (the shared space and tools) forces makers to work together and collaborate (El Safty interview, 2017). El Safty (interview, 2017) described IP as a "hassle in the maker community globally," where there is a constant debate between open source and proprietary IP measures. He elaborated by saying that makers usually do not like the idea of patents and other proprietary protection measures; they only resort to protection when a legal consultant advises them that this is the best option for their product (El Safty interview, 2017). According to El Safty (interview, 2017), out of the 15 startups that have businesses related to Fab Lab Egypt, only three have applied for patents for their innovations.

iii. Collaboration

In terms of collaboration within the makerspaces, we found, at Fab Lab Egypt, that while makers appreciate learning from each other, there is also fear of collaboration due to a competitive culture that exists (El Safty interview, 2017). Competition was also cited as a disincentive to collaborate at Qafeer Makerspace, in addition to unfamiliarity with the concepts of knowledge-sharing promoted by makerspaces (El Zoughby interview, 2017). We found that some makers fear that others will steal their ideas and bring them to market as their own. Although encouraged, collaboration at FLiNC is limited by the average group size working on a project, which is usually two people (El Raffei interview, 2017). The issues concerning makers in the spaces studied seem clearly to be matters of competition and secrecy, rather than matters of formal IP protection.

In Karakeeb Makerspace, we found that there is a trend towards collaboration and away from competitiveness, which can be partially attributed to the fact that Karakeeb is based in a cultural centre. Collaboration among makers was described as very prevalent in the space. In fact, the co-founders stated that people from different disciplines work better together and learn from each other (Effat and Hassan interview, 2017). Karakeeb Makerspace supports the open source ethos and tries to steer makers away from proprietary thinking (Effat and Hassan interview, 2017).

Similarly, ICE Alex advocates for an open source culture, where everyone learns from each other and collaboration is key (Bastawy interview, 2017). Because Fab Lab ENIT is currently restricted to the student community, educational values are shared and innovation is not approached as a competitive business model. This translates to the willingness of student makers to share their models and work as part of an open source platform (Ben Rejeb interview, 2017).

D. Innovation Scalability

The fourth set of questions addressed scalability. Scalability was an important issue to tackle in this research, as it relates to the expansion and growth of the maker movement in North Africa. To understand scalability in the makerspace context, we asked about the extent to which the scaling of innovations represented an opportunity or a threat for nascent entrepreneurs. We also asked how

makerspaces could play a role in ensuring that scaling-up included a sustainable knowledge-sharing process.

i. Perceptions of Scalability

In line with the discussion of scalability provided by De Beer, Armstrong, Ellis and Kraemer-Mbula (2017) in their analysis of maker movement findings in South Africa, we examined scalability not just as the process of turning innovations or ideas into a commercial business, but also as a process that includes other aspects such as the scaling of knowledge and knowledge-sharing. We concur with the De Beer et al. (2017) assertion that a narrow view of scaling, confined to a focus on the scaling of an idea to a commercial enterprise, is unnecessarily dismissive of the significance of knowledge-sharing as vital to the sustainability of the scaling process and outcome.

In an effort to explain the dynamic nature of scalability to our interviewees, we differentiated, in our questions, between scaling-up and scaling-out (also referred to as upscaling), whereby: scaling-up referred to commercialising innovations, and scaling-out referred to innovation-expansion via knowledge-sharing and the ensuing benefits.

ii. Scaling-Up

We found that opinions varied on whether seeking scalability presented opportunities or threats. Scalability was by many seen as an opportunity for entrepreneurs wishing to grow their businesses or wanting to penetrate markets. At the same time, some interviewees gave the view that the opportunity comes with associated risks, and that makers need to be weary of these risks before deciding to scale-up.

According to Fab Lab Egypt's general manager, El Safty (interview, 2017), the scaling of innovation represents both an opportunity and threat for nascent entrepreneurs. Scaling is an opportunity for growth, and it is a desirable outcome from a business point of view. Nevertheless, many makers delve into projects too quickly without conducting the needed feasibility studies for scaling their innovations. This results in a growth rate that is not supported by the maker's capabilities and is potentially threatening to the entire project. According to El Safty (interview, 2017), "scaling is a double-edged sword that you must take step by step". Similarly, according to FLiNC's manager, El Raffei (interview, 2017), scaling is perceived as a threat because it requires different sets of skills that are often beyond the capabilities of the founders of a startup. Karakeeb Makerspace co-founders also hold the view that scaling is both an opportunity and a threat, and that the threat is usually a legal rather than financial one (Effat and Hassan interview, 2017). Scalability was referred to as something that is not desirable for all makers who frequent Karakeeb; some makers visit Karakeeb to create and enjoy their time without thinking of establishing a business or scaling.

From the viewpoint of the director of Qafeer Makerspace, scalability is viewed as an opportunity, and always a desirable outcome, for nascent entrepreneurs. However, scalability is achieved through connections external to the makerspace. In cases where scalability has led to formalisation, makers went beyond the makerspace to accelerators to help them establish their formal businesses (El Zoughby interview, 2017). ICE Alex co-founder Bastawy (interview, 2017) explained that scaling is a desirable outcome and it is key when working with products. ICE Alex uses a human-centred design methodology: they start by identifying a challenge that is relevant to the community and then identify solutions viable for the makers and their model. This is done in order to incentivise scaling. Fab Lab

Casablanca's directors, Abouch and Kouska (interview, 2017) believe that scaling is a desirable outcome and they aim to support makers in formalising and growing their ideas. Alex Hackerspace co-founder El Shaer (interview, 2017) views scaling as an opportunity for nascent entrepreneurs, but as not always desirable.

At the time of our research, Level 1 Tunisia had yet to reach the stage where its makers were tackling the issue of scalability. However, co-founder Bouslama (interview, 2017) said that while he acknowledges that every business opportunity includes risks, he believes that scaling is an important opportunity for makers. The aim of Level 1, he said, is to provide a space where makers can develop their innovations to a point where they become more suited for entry into the market.

Fab Lab AUC co-founders Shalaby and Ragab (interview, 2017) said they believed that their Fab Lab did not have a significant role to play in relation to scaling; the makerspace primarily aided the maker in creating a prototype. Additionally, they explained that scaling is lacking in Egypt because many entrepreneurs do not think about growing their businesses.

The role of makerspaces, in Fab Lab ENIT director Ben Rejeb's (interview, 2017) opinion, is to provide makers with the opportunity to test their products. This will help them to develop these products to a point where they can enter the market (Ben Rejeb interview, 2017). Thus, he believes that scaling is a great opportunity and is usually the ultimate goal for nascent entrepreneurs.

iii. Scaling-Out (Upscaling)

The maker culture is still spreading, and thus, in our analysis, North African makerspaces are still learning about the various activities that can support scaling-out (upscaling). Fab Lab Egypt ensures that scaling includes a sustainable knowledge-sharing process through education, sharing, and collaboration. This is one of the core elements of the space. As Fab Lab Egypt interviewee El Safty said, "The key to doing this is working on the horizontal by giving every maker the same attention, and not just makers who have products that we think are marketable or profitable" (El Safty interview, 2017).

FLiNC hosts workshops to promote the scaling of products, and it also contributes to sustainable knowledge-sharing and scalability in cooperation with Fab Lab Egypt, through their Fab Lab on Wheels (FLoW) initiative (El Raffei interview, 2017). At the time of our research, FLoW had toured three Egyptian governorates, and was planning future visits to two more governorates. These tours aim to spread the maker culture and bring more people into the community.

Alex Hackerspace had an initiative wherein it purchased access to massive open online courses (MOOCs) that makers would otherwise not be able to afford on their own, and offer them for free. The course content was divided among the makers who sign up; each maker was then responsible for teaching their fellow makers about the section they had been assigned. This allowed the makerspace to introduce makers to different skills, including the skills needed for entrepreneurship and scaling-up businesses. According to the Alex Hackerspace co-founder, to ensure sustainable knowledge-sharing and scalability, there needs to be more support for existing makerspaces and an effort to introduce the concept of making within formal educational structures (El Shaer interview, 2017).

ICE Alex was found to be playing a role in spreading the making culture by connecting makers to the demand-side of the market, where they can provide their innovations as meaningful solutions to existing challenges. For example, the makerspace at ICE Alex produced Ramadan lanterns on a medium-scale when importing was restricted in Egypt, thereby filling a market gap during that season (Bastawy interview, 2017).

When asked how to upscale, promote, and encourage innovation, Karakeeb's Effat and Hassan (interview, 2017) explained that the key is not to focus on one product and scale it up; instead it is important to be involved in many innovative initiatives at the same time. Karakeeb plays a role in promoting innovation through providing technical assistance and know-how.

Fab Lab ENIT director Ben Rejeb (interview, 2017) said he aims to create more funding opportunities for innovation, such as via investment opportunities and crowd-funding. Fab Lab Casablanca's directors Abouch and Kouska (interview, 2017) emphasised that they support makers in scaling their innovations. They also regularly inform these makers of competitions that can help them to grow and share their prototypes. Abouch and Kouska (interview, 2017) described the role of the makerspace as being one that ensures that makers create a solid and high-quality product or innovation on a small scale that will later enable the maker, if the maker chooses to, to scale the innovation on his or her own.

E. Measuring Innovation

The final section of the semi-structured interview questions addressed the topic of measuring innovation, which was the most challenging set of questions for our interviewees. Makerspace staff were asked how the innovation that occurs in the spaces they operate can be better accounted for and documented. We sought open-ended answers to the question of how we can measure the creative outputs of makers. Additionally, we enquired about whether we can assess the openness of innovation and, if yes, then how? This set of questions aimed to explore how innovation that is unaccounted for in typical international innovation indexes can be captured, so as to better reflect innovation realities on the ground (see Rizk et al., 2018).

Two main views emerged in relation to how to better account for and document the innovation that takes place at makerspaces. The first view, held by the majority of our interviewees, was that an online platform can serve, and does serve in some instances, as a way of documenting innovation at makerspaces. Fab Lab Egypt, Fab Lab AUC, ICE Alex, Fab Lab ENIT, and Fab Lab Casablanca all recommended an online platform. At Fab Lab AUC, makers are required to document their creative outputs by uploading them to a cloud server (Shalaby and Ragab interview, 2017). ICE Alex uses a similar, but more accessible online approach, documenting creative outputs on their website, with pictures and relevant taglines (Bastawy interview, 2017). Fab Lab ENIT have a shared drive on which makers share their creative outputs, but director Ben Rejeb (interview, 2017) stated that they are working on an improved and more organised documentation method. Fab Lab Casablanca's directors Abouch and Kouska (interview, 2017) stated that the optimum way for innovation in makerspaces to be documented is to ensure that makers have a platform to share and receive credit for their creations.

The second main view that emerged from interview responses regarding how to better account for and document the creative outputs of makers was unique to the Egyptian respondents. Several of the makerspaces interviewed in Egypt referred to event data and statistics as a possible way to document the innovations taking place in makerspaces. FLiNC keeps documentation of the workshops it holds, and the different learning methods employed (El Raffei interview, 2017). As organisers of the annual Maker Faire in Cairo, Fab Lab Egypt's director stated that the statistics collected at the event could indicate the magnitude of the maker movement in Egypt (El Safty interview, 2017). Karakeeb Makerspace co-founders Effat and Hassan (interview, 2017) held the same view, elaborating that the annual Maker Faire in Cairo is an event where all makers in Egypt meet and showcase their work, allowing for documentation of the innovations taking place in makerspaces. The first Maker Faire in Egypt took place in 2015 in Cairo, and has since become an annual event, hosted by Fab Lab Egypt. In 2018, for the fourth year in a row, the event gathered makers from all over Cairo, as well as from other national and international destinations, to connect and collaborate on various innovations and educational aspects of the maker movement (Maker Faire Cairo, n.d.). Data from this event that gathers the majority of those who are part of the maker movement in Egypt can be very useful to analyse trends in this expanding ecosystem, and to help to identify existing gaps and challenges that need to be addressed.

Interviewees had varying responses regarding our question about measuring the openness of innovation. Gauging the degree and level of collaboration, however, was the most prevalent response received. Fab Lab Egypt's El Safty (interview, 2017) described that one way to do this is by studying collaboration patterns. Karakeeb co-founders Effat and Bastawy (interview, 2017) shared a similar viewpoint, citing the degree and willingness to collaborate as one way to measure the openness of innovation. Fab Lab ENIT's Ben Rejeb (interview, 2017) stated that the key is measuring the degree of collaboration, the degree of skills shared, and the number of people from different contexts involved in the innovation process. Fab Lab AUC co-founders said that in makerspaces where there is an online documentation platform, one can see how many times the same project was downloaded and to what extent it was modified and built upon, and thus account for the openness of innovation (Shalaby and Ragab interview, 2017). Level 1 Tunisia's co-founder Bouslama (interview, 2017) put forth a few propositions for measuring openness: examining the degree to which the innovation had access to shared tools and materials, how much the makers collaborated in groups to create the innovation, and how much they used open source sharing methods throughout the innovation process. Alex Hackerspace's El Shaer (interview, 2017) contended that it is difficult to assess the openness of innovation, as some makers are willing to share, while others are protective of their work.

V. Conclusions

The global maker movement is growing, and this growth trend is mirrored across North Africa as well. Makerspaces should not be viewed as autonomous solutions to the unemployment dilemma of North African countries, but they should be capitalised on as local solutions to the many socioeconomic and political challenges currently being faced in these countries. As exemplified by our research, makerspaces across North Africa aim to address local problems in innovative ways at low costs. Makerspaces also create environments where voluntary learning takes place and opportunities for skills development arise. While makerspaces have an entrepreneurial spirit, evidence linking

makerspaces to job creation was sparse. And despite the growth of the maker movement in North Africa, these spaces have not yet developed self-sustaining models. Lack of, or inadequate funding, was cited by most of the interviewees as a major challenge that makerspaces face. Another challenge is registration, as countries in North Africa do not have a clear-cut stand on how makerspaces should register.

According to interviewees, makerspaces share an open source ethos. However, makers are still reluctant to share and collaborate with others for fear of copying. This is despite the open and collaborative environment that the makerspaces offer, a sentiment that was echoed by all our interviewees, except for the spaces used by students. Due to the academic nature of their projects, students prefer to work alone.

We found that the influence of intellectual property on the innovation processes taking place in the makerspaces that were part of this study is, at present, negligible. Once pre-makers become pro-makers, issues of formal IP protection will likely arise. The maker culture is still growing and spreading, and thus makers and the products being created have not reached the state where protection or formalisation are issues to consider.

Opinions varied on whether scaling presents an opportunity or a threat in the context of makerspaces. Scaling was cited as an opportunity for entrepreneurs wishing to grow their businesses or to penetrate markets. It was discussed as a threat for those who scale without devising proper business models to sustain the scalability. As described by Fab Lab Egypt's El Safty (interview, 2017), "scalability is a double-edged sword". Nevertheless, we found that most of the makerspaces included in this study were engaged in activities that support upscaling and the ensuing sustainable knowledge-sharing processes.

Makerspaces are dynamic entities. As they become more developed and establish strong communities of practice, the nature of their functions develop. We saw this in the case of Fab Lab Egypt, which changed its role from being a makerspace that delivers workshops related to making, to more of a "caretaker" role for other makerspaces in the country. The dynamic nature of makerspaces warrants further research into the matter. It is likely that as time passes, the types of innovations and creative practices occurring in makerspaces will change. Further research is needed to continue to understand more about the linkages between makerspaces and entrepreneurship, and the role makerspaces can play in influencing development.

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Appendices

Appendix I: Semi-Structured Interview Questions

1. About the makerspace (for makerspace director/staff)
    a. When did you first hear of the concept of a makerspace?
    b. When was this makerspace established?
    c. Tell us about the model that this makerspace follows.
    d. Was this makerspace built from scratch, or is it upgraded from a previous older space (like a library)?
    e. Where any of the tools you purchased brand new? Or are they mostly refurbished unused products?
        i. Did you receive financial support in purchasing these tools? If yes, from who? And how long will the support last?
    f. Are there any charges incurred on the makers to cover costs, like using a 3D printer?
    g. What is the gender ratio in your makerspace?
    h. How is maintenance and repairs performed on certain tools within that makerspace? Is it done via a professional service or by makerspaces?
    i. Do you collaborate with other makerspaces, locally or globally? If yes, how?
    j. How are (can) linkages across informal enterprises (be) stimulated in various contexts?

2. Creative processes and knowledge-sharing (for makerspace director/staff)
    a. What type of innovation takes place in this makerspace?
    b. What type of learning occurs in this makerspace?
    c. What type of skills (if any) are introduced to the makers?
    d. Among those that attend and use the makerspace, do any of them learn skills that help them find employment later on?
    e. If there are people working in groups, do they learn from each other? Or do they learn from a teacher or mentor?
    f. What is the group size of people working on a single project?
    g. How can makerspaces help attract new potential entrepreneurs?
    h. Are there any specific examples or cases were a product was created to solve a specific problem in your area?
    i. Do people drop in at the last minute, or do they plan to come?

3. IP and informality
    a. What, if any, are the specific IP-related solutions and unique challenges for scaling up informal businesses?
    b. Have there been any social issues or arguments between makers regarding ownership? If so, how were they resolved? Where these issues resolved legally or through arbitration?
    c. What rules govern the relationship between informal businesses and formal counterparts if and when they decide to engage?
    d. Which online portals do you go to, to find 3D models to download?
    e. Does the space play a role in deciding who owns specific inventions created there? Or is there no monitoring of the process.
    f. Is there any assisted legal process for makers who wish to implement copyright their inventions?

4. Scalability
    a. Does scaling of innovation represent an opportunity or a threat for nascent entrepreneurs, and

how can makerspaces play a part in ensuring sustainable access to knowledge for all?

b. Is scalability a desirable outcome?
c. In cases where scalability leads to formalisation, are we dealing with the formalisation of the innovation itself or the formalisation of the "informal" entity?
d. How can we upscale informal innovation in a way that creates more informal innovation—"scaling out"?
e. Were there any products that were produced, which were eventually manufactured?

5. Measuring innovation
    a. How can the innovation taking place in makerspace contexts be better accounted for and documented?
    b. How can we measure the creative output of the maker and the informal entrepreneur?
    c. Investigating specifically knowledge creation within the sphere of the maker, the informal entrepreneur and the formal entrepreneur: can we assess the openness of innovation? How?

Appendix II: List of Interviewees

Interviewee Name	Title	Affiliated Makerspace
Omar El Safty	Director	Fab Lab Egypt
Ahmed Mahmoud El Zoughby	Director	Qafeer Makerspace
Mohamed El Raffei	Director	Fab Lab in New Cairo (FLiNC)
AbdelRahman Shalaby and Mohamed Ragab	Founders	Fab Lab AUC
Amr El Shaer	Co-Founder	Alex Hackerspace
Mina Effat and Rabab Hassan	Co-Founders	Karakeeb Makerspace
Ahmed Bastawy	Director	Ice Alex
Yassine Abouch and Ahmed Kouska	Founders	Fab Lab Casablanca
Riyadh Bouslama	Co-Founder	Level 1 Tunisia
Helmi Ben Rejeb	Director	Fab Lab ENIT

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