A Scan of South Africa's Maker Movement

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Abstract

This working paper provides findings from a scan of South Africa's maker movement. The national scan, conducted in 2016-17 by members of the Open African Innovation Research (Open AIR) network, gathered data on more than 20 maker communities across five South African provinces. Adapting grounded theory-building, situational analysis, and action research methods, we identified a set of 12 variables, covering a range of management, spatial and activity aspects of maker communities. Our iterative identification of these variables from the collected data provided us with a framework that can be used, and where necessary further refined, in other national maker movement scanning exercises, thus allowing for elements of internationally comparative research among national maker movements. The data that emerged from the scan helped identify several sustainability themes that we feel warrant further investigation in the South African context and in other national contexts: stability of funding and revenue model; establishment of niches, reputations and brands; knowledge appropriation and intellectual property (IP); elements and degrees of institutionalisation; robustness of communities of practice; embeddedness in broader networks; orientations towards innovation and enterprise development; and socioeconomic inclusion. The data also provided evidence of approaches to innovation-scaling that are broader than commercialisation.

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Keywords

maker movement, South Africa, communities of practice, sustainability, scalability, innovation, informal innovation, institutionalisation, formalisation, branding, networks, knowledge appropriation, intellectual property (IP), enterprise development, socioeconomic inclusion, gender, skills development

I. Introduction

The "maker" movement encourages re-adoption of do-it-yourself (DIY) approaches to innovation. By urging consumers to be creators, and encouraging tinkering and learning in hands-on environments, the movement is re-appropriating production ideals of pre-industrial times. Yet the post-industrial potential of the maker movement is just beginning to be realised.

The maker movement as we generally discuss it today was first formally labelled as such in the United States at the time of the launch of the online *Make* magazine, in 2005 *(Make*, n.d.; Dougherty, 2012). The first Maker Faire was launched in the US the following year, by the same group behind *Make* magazine. Maker Faire events host makers displaying products they have made, created, or invented using technological or trade tools and openly shared knowledge (Maker Faire, n.d.).

The discourse of a "movement" may sometimes obscure the fact that there are, in reality, many distinct and heterogeneous groups of "makers" that make up that movement. Maker communities—called "collectives" in Kraemer-Mbula and Armstrong (2017)—may, or may not, be centered around one physical location or fixed space, a "makerspace". An excellent way to understand associations between individual makers, maker communities, makerspaces, and the maker movement is as Galaleldin and Anis (2017) suggest, to view them as examples of "communities of practice". They build on the conceptualisation of communities of practice by Wenger (1998) and Wenger et al. (2002). At the core of makers' communities of practice is the activity of making. Making activities have been described as "creative production in art, science and engineering where people of all ages blend digital and physical technologies to explore ideas, learn technical skills, and create new products" (Sheridan, 2014).

In this paper and related research of the Open African Innovation Research (Open AIR) network, we define maker communities as groups of people who, regardless of their location or access to space, and with varying degrees of informality and formality, support, allow, and encourage making. We further conceive making, in line with conception cited above from Sheridan (2014), as transcending specific disciplines to cover art, science, and engineering. We also see making as applying creative

skills using technologies and tools both digital and analogue, and both virtual and physical, and we see maker community activities as driven by values of collaboration, experimentation, and problem-solving.

Research on making, the maker movement, makerspaces, hackerspaces, FabLabs, and other places where makers interact, is growing rapidly. Some of this research is indexed in databases of published literature, like SCOPUS, Web of Science, SSRN, and Google Scholar, and at least two peer-reviewed journals have devoted special issues to makerspaces and related matters: the *Journal of Digital Learning in Teacher Education* (forthcoming, 2018), and the *Journal of Peer Production* (2014; forthcoming, 2018). Perhaps the best-known book on the movement, Anderson's *Makers: The New Industrial Revolution* (2012), explores the maker movement against the backdrop of the Industrial Revolution, declaring that the movement represents the "New Industrial Revolution". Other key works on the movement in general include those by Hatch (2014) and by Doorley et al. (2012). Additional insights can be gleaned from practice-oriented works, which tend to be published through blog postings, event reports, and other informal channels.

Several key themes emerge from the formal and informal literature about the maker movement.

A. Institutionalisation and Equipment

Elements of institutionalisation have been present from very early on in the maker movement, via the creation of makerspaces. These are spaces giving access to shared tools and knowledge, and they have emerged among private citizens, in universities, in public libraries, in grade schools, and as businesses (Dougherty, 2012; Educause, 2013; Wang et al., 2015). There is an especially large body of research addressing makerspaces located in libraries, because so many makerspaces are located in these inherently multi-disciplinary places (Brady et al., 2014; De Boer, 2015; Moorefield-Lang, 2015b; Pryor, 2014; Slatter & Howard, 2013).

The tools typically found at makerspaces include 3D printers, laser-cutters, and computer numeric control (CNC) machines, as well as trade tools such as woodworking tools, welding equipment, and sewing machines (Lorinc, 2013; Wang et al., 2015). Members of makerspaces engage in personal or collective projects that range from wood-working and welding to computer programming and robotics, using materials that include microcontrollers, sensors, broken electronics, discarded wood or metal scraps, and recycled materials (Anderson, 2012).

Important research has been conducted on the policy implications of 3D printers—tech tools which are sometimes seen as defining makerspaces. Intellectual property (IP) issues related to 3D printing are significant (Dagne, 2015; Rimmer, 2016; 2017). A recent World Intellectual Property Organisation (WIPO) report on *3D Printing and The Intellectual Property System* makes mention of the maker movement (Bechtold, 2015).

B. Education and Skills Development

Some authors focus on the maker movement as primarily an educational opportunity (Peppler et al., 2016a; 2016b). Dougherty (2012) and Anderson (2012) discuss how the movement has the potential to be transformative for students, giving them enhanced practical experience and more control over the direction of their education. A report by the American Society for Engineering Education (2016) looks at the maker movement's potential to contribute to learning, teaching, diversity, accessibility, new technologies, and innovation in the future. A study by the US Association for the Advancement

of Computing in Education positions the maker movement as part of a re-thinking of approaches to school curricula, emphasising the role of digital fabrication and makerspaces in competency-based curricula in which the learning is practical as opposed to abstract (Kim & Ruters, 2016).

There is also a growing body of master's and doctoral research into experiential learning via making, including research into the learning effects of makerspace environments (Krishnan, 2015; Manas Pont, 2014); makerspaces as facilitators of educational programmes (Lacy, 2016; Litts, 2015; Raison, 2010; Shin, 2016); and the engagement of specific groups such as children or university students with makerspaces (McCubbins, n.d.; Weinmann, 2014). The maker movement is seen as especially empowering for youth, by enabling them to learn-by-doing, showing them how to use tools and technologies, and allowing them to gain confidence as they see what they are capable of creating (Eha, 2016; Ekekwe, 2015).

Other researchers look at the possibilities the maker movement holds for women and vulnerable communities (Nguyen et al., 2016; D'Ignazio et al., 2016; Van Holm, 2015), and how makerspaces can play a role in the advancement of science, technology, engineering, and mathematics (STEM) skills (Kera, 2012; Kurti et al., 2014; Sheridan et al., 2014). Braybrooke, for example, writes about the use of hacking to bolster female presence in the area of coding and as a tool to give consumers back freedom from technology companies (Braybrooke, 2013; 2015).

C. Innovation and Entrepreneurship

Several researchers show how local innovators are using makerspaces to identify opportunities for experimentation and entrepreneurship (Yoder, 2015). For example, Lorinc (2013), Hersman (2013), and Peppler and Bender (2013) have all written about the interface between makerspaces and innovation. King, of the US Global Development Lab, describes the maker community as a "global network of innovators who are capable of solving problems in a way that's never been possible before" (Making Sense, 2014). It is also argued that making can positively impact the economy by creating job opportunities and opening the doors to informal ways to innovate (Hatch, 2014; Wang et al., 2015).

The maker movement is part of, perhaps emblematic of, renewed interest in user innovation (Von Hippel, 2005). User innovators exist in a dynamic ecosystem of peer production (Benkler, 2006), characterised by open collaborative innovation (Baldwin & Von Hippel, 2011). This conception is not to be confused with an alternative conception of open innovation which focuses on *firms'* openness to licensing IP with others (Chesbrough, 2006). The sort of open innovation associated with makers typically has little to do with formalised IP concerns, and has recently been labeled as "free" innovation (Von Hippel, 2016).

D. Socioeconomic Development

The Dutch initiative Making Sense (2014) hosted an event and generated material about the potential impact the movement can have in developing countries. An Open AIR workshop at the University of Ottawa in 2016 produced a series of blog posts highlighting issues for analysis in both developed and developing countries (Boots, 2016; Ellis, 2016; Jain & De Beer, 2016), and partly contributed to a proposed university initiative on entrepreneurship, innovation, and appropriate technologies (Lalande, 2016). Similarly, the University of Sussex Science and Policy Research Unit hosted a workshop on "Makerspaces and Sustainable Development" with resulting online articles

(Makri, 2015; Oxley, 2015) and a peer-reviewed journal article (Hargreaves et al., 2013).

E. The African Innovation Context

The maker movement has a growing presence in Africa. The first African Maker Faire, coordinated by a Ghanaian entity and separate from the US-based Maker Faire brand mentioned above, was staged in Ghana's capital, Accra, in 2009 (Maker Faire Africa, 2009). There were then four more Maker Faire Africa gatherings, in Nairobi (2010), Cairo (2011), Lagos (2012), and Johannesburg (2014).

The US Maker Faire brand has also found its way to Africa, including two South African appearances: the 2015 Maker Faire Cape Town and the 2016 Mini Maker Faire, Cape Town. A significant amount of online material has emerged from these events.

Ekekwe (2015) and Yoder (2015) write about how the maker movement provides an opportunity for growth across the continent, and Hersman (2013) writes about the interface between makerspaces and innovation in Africa. Waldman-Brown et al. (2013) posit that Ghana's informal-sector innovators can benefit, and avoid stagnation, through linkages with formal governmental and NGO actors. In turn, according to another piece of Waldman-Brown research (2014), Ghana's FabLabs and makerspaces, as somewhat formalised technological workshops, need to build strong linkages with informal-sector artisans' workshops.

F. Objectives, Scope, and Structure of this Paper

This study is situated within the broader research agenda and objectives of the Open AIR network. Open AIR's exploration of the role of makers is grounded in foresight research (Elahi & De Beer, 2013) that anticipated three possible scenarios for the future of knowledge and innovation in Africa: (1) a future dominated by high technology hubs; (2) a future of predominantly informal innovation; and (3) a future of Indigenous knowledge and entrepreneurship. The maker movement is potentially relevant across all of these future scenarios.

Previous Open AIR research has demonstrated the collaborative dynamics of innovation in Africa (De Beer et al., 2014). Open AIR researchers are now investigating how collaboration can facilitate the scaling-up of innovation, and which policies will best ensure that benefits of innovation are shared inclusively.

To deepen understanding of the emerging maker communities in Africa and their importance for Africa's futures, Open AIR is supporting a group of studies on the continent. Through this new research, we are testing the hypothesis that maker communities can play a role in incubating and then scaling up innovation. In addition to the South African national scan on which this article is based, Open AIR research related to the maker movement is underway in Egypt, Tunisia, Morocco, Ghana, Ethiopia, and Kenya.

This is the second Open AIR working paper published about makers. The first provided an in-depth look at maker communities—"collectives" according to the framing of that paper—in South Africa's Gauteng Province (Kraemer-Mbula & Armstrong, 2017). Kraemer-Mbula and Armstrong's paper contains in-depth analysis based on interviews in one particular province of South Africa; this paper offers a less detailed, but broader, national scan.

One of the purposes of this scan, initially, was to experiment with data collection methods and different variables, in order to begin to develop a framework for comparative research elsewhere on the continent. While the literature is diverse and growing, there was (and still is) no well-established methodological framework for data collection on, and no theoretical framework for analysis of, maker communities and movements in developing-world contexts of the sort found on the African continent. Given the methodological and theoretical gaps around maker movement research in Africa, we were not certain whether research tools specifically tailored to the maker movement would be necessary, whether standard social scientific approaches from studies of makers elsewhere in the world would be sufficient, or whether an *ad hoc* approach to assessing maker movements would just as effectively yield comparable results. To provide full disclosure: We began this scan not settled on our methods.

However, as we progressed, we adopted an approach consistent with the overarching methodology guiding Open AIR's entire programme of research. The Open AIR approach generally combines grounded theory-building, situational analysis, and action research methods. Grounded theory-building develops new conceptual models based on real-world empirical evidence (Eisenhardt, 1989; Glaser & Strauss, 1967). For Open AIR, these methods enable ground-up analysis of observations to develop and validate new theoretical models potentially useful to the community(ies) studied and to others engaged in the topic. For example, for this scan, we did not use an entrenched framework or pre-defined variables to collect data. Rather, the relevant variables we present in this paper emerged *from* our desk research and on-the-ground fieldwork, and developed into our framework for description and analysis. In these kinds of processes, Open AIR researchers generally adapt Clarke's (2005) methods of situational analysis, which are especially well-suited for practice-oriented action research such as ours. While we do not in this paper alone purport to produce entirely new theory, our insights do facilitate and contribute to such theory-building, by ourselves and others.

Lewin (1946) first coined the term "action research" to describe a way of conducting social science that links the generation of theory to changing a social system through action. In this regard, action research provides a methodological framework that allows for generation of knowledge about a system by changing, with the changes driven by seeking solutions to challenges. Action research therefore brings together researchers with members of an organisation or community that is seeking to improve its situation. In action research, data are collected through the process of collectively finding practical solutions involving the communities being researched, in this case the communities of makers.

Through our grounded theoretical and action research approaches, we identified a set of 12 variables, covering a range of management, spatial, and activity-related aspects of South African maker communities. Our iterative refinement of these variables from multisource data resulted in a framework that is potentially useful not only for our findings but also for research on maker movements in other countries in Africa and nations, both developing and developed, beyond the continent.

The next section of this paper outlines the data collection methods, followed by sections providing our findings, our analysis and conclusions, and our planned next steps.

II. Data Collection Methods

We collected our primary data on South African maker communities, between early 2016 and the middle of 2017, via the following means:

- desk analysis of each collective's online presence, supplemented with email correspondence;
- in-person site visits to the premises of maker communities, including attendance at certain communities' weekly meet-ups;
- informal in-person and videoconference/audioconference discussions with participants in communities;
- formal, recorded, in-depth research interviews with participants, conducted in-person and via videoconference/audioconference;
- convening of a national South African maker movement stakeholder workshop in Pretoria in March 2017, attended by 50 participants, including representatives of South African maker communities from three provinces and by representatives from relevant South African government departments, state agencies, and NGOs;
- video-recorded interviews with makers during and after the Pretoria workshop; and
- reading of post-workshop documents distributed by the South African Maker Collective.

A snowball sampling method generated referrals from one maker or maker community to another. When our research began in early 2016, we were initially only aware of maker communities present in the country's four largest urban areas: Johannesburg, Pretoria, greater Cape Town, and Durban. However, in the course of the research, we became aware of additional communities in the cities of Port Elizabeth, Bloemfontein and Ekuherleni, and in the town of Knysna. We also witnessed the emergence of new maker communities during the course of our research,[1] and still more maker communities in their planning stages.[2]

It was not possible to collect primary data on all of the maker communities we became aware of, and by the time this research is published there will likely be additional communities. (And one grouping that we felt could be characterised as a maker community did not self-identify as such and opted to be excluded from our study.)

Some individuals and institutions we engaged with were not maker communities but instead were another sort of relevant but hard-to-classify actor in South Africa's maker ecosystem. For example, the Additive Manufacturing Unit at the Vaal University of Technology (VUT) science park in Sebokeng and the Centre for Rapid Prototyping and Manufacturing at the Central University of Technology (CUT) Science Park in Bloemfontein operate on a much larger scale than the typical maker collective. Such large-scale operations use equipment—including 3D printers and CNC machines—that is technologically similar to units in makerspaces but is far larger and far more expensive than what one could expect to find in makerspaces. While the VUT and CUT additive manufacturing operations' activities include prototyping, it is primarily done by highly-trained technicians to fulfil industrial contracts, not by do-it-yourselfers testing a small-scale product idea. While these flagship enterprises located in university science parks are not, to us, maker communities, they may spin off,

[1] For example, Made In Workshop, ZS6COG Fablab, Tsakane FabLab, Duduza FabLab and Soweto eKasi Lab.

[2] For example, Vosloorus FabLab and the maker facilities planned for eKasi Lab Alexandra, eKasi Lab Mohlakeng and eKasi Lab Sebokeng.

or synergise with, maker communities in various ways. At a certain scale we drew a line between small-scale making and industrial manufacturing, even though the line is not always entirely clear.

Table 1 below provides a provincial breakdown of all the communities we were able to collect primary data on, and a listing of our primary data sources for each.

Table 1: Maker Communities Studied and Sources of Primary Data

Province	Maker Community	City/town	Year of Formation	Sources of Primary Data
Gauteng Province	House4Hack	Centurion	2011	online presence, email correspondence, site visit, informal discussions, formal interviews, national workshop, video interview at workshop
	BinarySpace	Vanderbijlpark	2012	online presence, email correspondence, site visit, informal discussions, formal interviews, workshop participation, video interview at workshop
	Tinker Space, University of Johannesburg (UJ) Resolution Circle tech hub	Johannesburg	2012	site visit, informal discussion
	Makerlabs	Johannesburg	2013	online presence, site visit, formal interviews
	Geekulcha Makers	Pretoria	2014 (Geekulcha founded in 2013, its Geekulcha Makers programme in 2014)	online presence, email correspondence, site visit, informal discussions, formal interviews, national workshop, video interview at workshop
	Sebokeng FabLab, Vaal University of Technology (VUT) tech hub	Sebokeng	2014	online presence, site visit, informal discussion
	Ekuherleni FabLabs (Thokoza, Tembisa, Tsakane, Duduza)	Ekuherleni	2011-16	online presence
	Digital Innovation Zone (DIZ) Maker Space, University of the Witwatersrand (Wits) Tshimologong tech hub	Johannesburg	2015	online presence, site visits, informal discussions, formal interview, national workshop, video interviews at workshop

	University of Pretoria (UP) MakerSpace	Pretoria	2015	online presence, site visits, informal discussions, formal interviews, national workshop, video interview at workshop
	eKasi Lab Ga-Rankuwa	Ga-Rankuwa	2015 (Lab established in 2014, maker-type work in 2015)	online presence, site visit, informal discussions, formal interviews, national workshop
	I Make Makers Lab, Makers Village	Irene	2015 (Makers Lab established in 2015 as part of existing Makers Village)	online presence, site visit, informal conversations, formal interviews, national workshop, video interview at workshop
	Made In Workshop	Johannesburg	2016	online presence, site visit, informal discussion
	eKasi Lab Soweto	Johannesburg	2016	online presence, site visit, informal discussion
	ZS6COG Fablab (formerly BNT Masinga Trading and Projects)	Heidelberg	2016	online presence
Western Cape Province	Kluyts MakerSpace	Knysna	2012 (in present factory location since 2015)	online presence, email correspondence, informal Skype discussion
	Craft and Design Institute (CDI) Product Support Space	Cape Town	2013 (the broader CDI was established, as the Cape Craft and Design Institute (CCDI), in 2001)	online presence, site visit, informal discussion
	Workspace	Cape Town	2013	online presence, site visit, informal discussion
	Curiosity Campus *	Cape Town	2013	site visit, informal discussion
	The Bank	Cape Town	2014	online presence, site visit, informal discussion
	Maker Station	Cape Town	2014	online presence, email correspondence, site visits, informal discussions, national workshop, video interview at workshop

	Modern Alchemists, Women in Tech Cape Town, Arduino Cape Town (all coordinated by KATO Technology)	Cape Town	2014	online presence, informal discussions, national workshop, video interview at workshop
	University of Cape Town (UCT) Maker Society*	Cape Town	2015	online presence, email correspondence, site visit, informal discussions, national workshop, video interview at workshop
KwaZulu-Natal (KZN) Province	The MakerSpace	Durban	2013	online presence, email correspondence, site visit, informal discussions, formal Skype interview, national workshop, video interview at workshop
Free State Province	Bloemfontein FabLab, Central University of Technology (CUT) tech hub	Bloemfontein	2006 (not a vibrant makerspace until recent years)	online presence, site visit, informal discussion
Eastern Cape Province	WERK	Port Elizabeth	2014	online presence

* the Curiosity Campus and UCT Maker Society in Cape Town were no longer active at the time of finalisation of this Paper in late 2017.

In addition to data collection on the above-listed communities, we also collected data from certain initiatives and bodies that support, or have links to, the South African maker movement. These entities, and the primary data sources used, are listed in Table 2 below:

Table 2: Supporting Entities and Field Research Data Sources

Entity	Location	Sources of Primary Data
South African Maker Collective	nationally dispersed network	online presence, email correspondence, informal discussions, formal interviews, national workshop
Maker Library Network (MLN)	internationally dispersed network	online presence, informal discussions with MLN partner makerspaces
htxt.africa	online news site, managed from Johannesburg	online presence, informal discussions, formal interview, national workshop

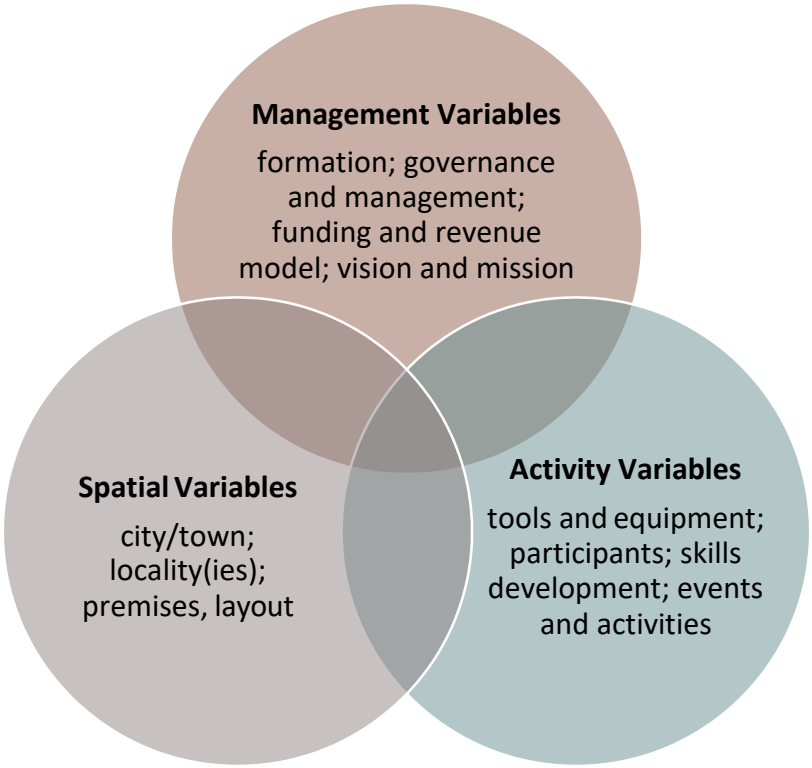
III. Findings

As the data came in, we arrived at the view that the maker communities were best understood in terms of three categories of variables:

- **management variables:** formation; governance and management; funding and revenue model; vision and mission
- **spatial variables**: city/town; locality(ies); premises; layout
- **activity variables**: tools and equipment; participants; skills development; events and activities

Thus we arrived at 12 variables across the three sets, as illustrated in Figure 1 below.

Figure 1: Variables



We acknowledge that often a variable will have dimensions or characteristics that overlap to some extent with another variable or variables, but feel the distinctions we have drawn carry value as a means to generating a descriptive framework for charting similarities and differences among maker communities.

In the *management variables* category, we viewed the "governance and management" variable as key, informing as it does the "formation", "funding and revenue model", and "vision and mission" variables also in that category.

Our *spatial variables* category covers aspects of geographic location as well as design and layout of premises. In respect of geographic location, in the context of South Africa, with its legacy of spatial segregation of the population and deliberate underdevelopment of townships and "locations" next to cities and towns, it is important to understand not just the city or town in which a maker

community locates its activities, but also the particular locality or localities it serves. Identifying the specific locality or localities served by a maker community also helps shed light on the innovation ecosystem it is part of. (We discuss this in more detail in below.)

Our *activity variables* seek to take account not only of tools and equipment, participants, and events and activities, but also the skills development objectives underpinning the events and activities.

A. Management Variables

Table 3 below provides an overview of the data we were able to collect in respect of management variables. (We do not include maker communities for which only online data were collected without follow-up communication).

Table 3: Management Variables

Maker Community	Forma-tion	Governance and Management	Funding and Revenue Model	Vision and Mission
House4Hack	2011	governed and managed by member volunteers	member donations, fees from course offerings, fees from corporate partnerships	"an initiative to bring together technology specialists and entrepreneurs in an informal setting [...] trying to combine concepts from hackerspaces and innovation incubators" (www.house4hack.co.za/about)
BinarySpace	2012	governed and managed by member volunteers	member donations, membership fees, fees from course offerings, corporate sponsor	"a space where people with common interests in technology, science and electronic art, can meet, socialize and/or collaborate" (www.binaryspace.co.za)
Tinker Space, University of Johannesburg (UJ) Resolution Circle tech hub	2013	governed and managed by university-owned company	funded by university-owned company	Resolution Circle, of which Tinker Space is part "is a technology ecosystem that commercialises technology and develop engineering skills" (www.facebook.com/pg/ResolutionCircle)
Makerlabs	2013	governed and managed by member volunteers	member donations, membership fees, fees from course offerings	community "of makers, of open software (opensource) and open hardware. Home to 3D printing, Repraps, electronics, Arduino, RaspberryPie, Python and a bit of beer brewing" (www.meetup.com/en-AU/Makerlabs-co-za)
Geekulcha Makers	2014	governed and managed by paid Geekulcha staff	project partnerships with governments (foreign, national, provincial, local), private sector, universities, schools	"enables Digital Makers with tools, innovation platforms and a network for collaboration and co-creation [...] to stimulate the notion of More Consumers than Producers [...] building the world we want to see. It's about Collaboration and Co-creation" (http://makers.geekulcha.com/about)

Sebokeng FabLab, Vaal University of Technology (VUT) tech hub	2014	governed and managed by the university	university funds	"enable grassroots inventions by providing a platform where communities can have access to advanced tools that can help people make products to address local needs" (www.vut.ac.za/fablab/)
Digital Innovation Zone (DIZ) Maker Space, University of the Witwatersrand (Wits) Tshimologong tech hub	2015	governed by the university, managed by private firm	university funds, membership fees	"shared knowledge and shared skills […] come in with an idea and actually walk out with a physical prototype" (interview with community participant)
University of Pretoria (UP) MakerSpace	2015	governed and managed by the university	university funds	"a creative laboratory where people with ideas can get together with people who have the technical ability to make these ideas become a reality" (www.library.up.ac.za/makerspace)
eKasi Lab Ga-Rankuwa	2015	governed and managed by government (provincial and local)	government funds (provincial and local)	"take innovation to the people by establishing co-creation and innovation spaces in the townships where local communities are able to access the services and facilities [...] for the community and unemployed youth so that employment is created in their area of residence through skills and enterprise development" (www.facebook.com/pg/ekasilabs)
I Make Makers Lab, Makers Village	2015	governed and managed by non-profit foundation	proceeds from Makers Village (design and production services craft sales, restaurant, entertainment venue), funds from government, private sector	"the perfect place to gain skills on digital fabrication. Whether you use it as an individual, or in a workshop through your school, or as an inventor or entrepreneur, it helps you put your dreams and ideas into real [life]" (www.facebook.com/pg/imakersvillage)
Made In Workshop	2016	governed and managed as a private business	membership fees, sale of consumables, proceeds from training offerings	"a shared fabrication studio and makerspace. We provide access to tools and industrial machines to people and business who would normally not have access to such facilities" (http://madeinworkshop.co.za)

eKasi Lab Soweto	2016	governed and managed by government (provincial and local)	government funds (provincial and local)	"take innovation to the people by establishing co-creation and innovation spaces in the townships where local communities are able to access the services and facilities [...] for the community and unemployed youth so that employment is created in their area of residence through skills and enterprise development" (www.facebook.com/pg/ekasilabs)
Kluyts MakerSpace	2012	governed and managed as a non-profit by Eden Community Initiative; also linked to a private business (Kluyts & Co. furniture store)	space rental fees	"We celebrate artists, craftsmen and product makers. We believe communities add value in workshops and real economies are built on building things of value. We enable makers by networking, equipping, resourcing and supporting them in a collaborative space" (www.facebook.com/pg/kluytsmakerspace)
Craft and Design Institute (CDI) Product Support Space	2013	governed by multistakeholder CDI Board, managed by paid CDI staff	government funds (national, provincial, local)	The CDI is "a craft and design sector development agency with a mission to develop capable people and build responsible creative enterprises trading within local and international markets" (www.thecdi.org.za/?page=about_us) The CDI Product Support Space is "an assisted DIY facility empowering and helping craft producers, designers, students, and other individual businesses to develop new, and refine existing product" (www.thecdi.org.za/?page=dev_product)
Workspace	2013	governed and managed by non-profit organisation	start-up funding from the British Council's Maker Library Network (MLN), project partnerships with local NGOs, donations, membership fees, space rental fees	"a platform for knowledge and skills exchange across the social, cultural and generational divides […] resources for all people from all backgrounds, ages and abilities to use "making" as a tool for empowerment, economic opportunity and the building of social capital […] a creative space for makers to engage, make and display their crafts" (www.workspace.org.za/about)
The Bank	2014	governed and managed as a private business	member donations, membership fees, space rental fees	"contemporary design space promoting innovation, collaboration, mentorship, idea exchange and business development" (www.wdccapetown2014.com/projects/project/464)

Maker Station	2014	governed and managed as a private business	user fees, membership fees, rentals, workshops, training, events	"a shared Maker, DIY, Hacker, Hobbyist, Designer, Prototyping, Art, Craft, and creative space, to build your projects of any size" (www.facebook.com/pg/makerstation.co.za)
Modern Alchemists, Women in Tech Cape Town, and Arduino Cape Town (all coordinated by KATO Technology)	2014	governed and managed by KATO Technology (a private business)	project partnerships, member contributions,	Modern Alchemists: "Anyone that is into coding, gaming, electronics, music, making, etc come to these meetups to meet like minded people, skill swop, learn, make, watch, ask for advice" (www.linkedin.com/in/robynfarah) Women in Tech Cape Town: "a community designed to empower females who are in tech or want to learn more about tech" (www.kato.global/wit)
University of Cape Town (UCT) Maker Society	2015	governed and managed by students	member contributions	"aims to connect multiple disciplines across the university in creating and inventing together. We focus on workshops, build days and exhibitions designed to help students grasp the practical aspect of building and designing" (www.facebook.com/pg/UCTmakersociety)
The MakerSpace	2013	hybrid: governed and managed by member volunteers alongside a private business	hybrid, including donations, start-up funding from the British Council's Maker Library Network (MLN), membership fees, member donations, fees from course offerings, aligned commercial projects and services.	"is about lowering the barriers of entry for people to express their creativity in a physical way. It is about people getting together, working creatively, inspiring each other, engaging with new technology, and building a 'bottom-up economy' " (http://themakerspace.co.za/what-we-are-about)
Bloemfontein FabLab, Central University of Technology (CUT) tech hub	2006	governed and managed by the university	university funds	"enable grassroots inventions by providing a platform where anyone can have access to advanced tools that can help people make products to address local needs […] peer-to-peer learning which enables anyone with or without a technical background to learn and have a space to experiment" (www.cut.ac.za/fablab)

Looking across the data obtained in relation to management variables, one potentially important distinction can be made between the maker communities with pronounced elements of institutionalisation and the maker communities with only light-touch institutionalisation. In our

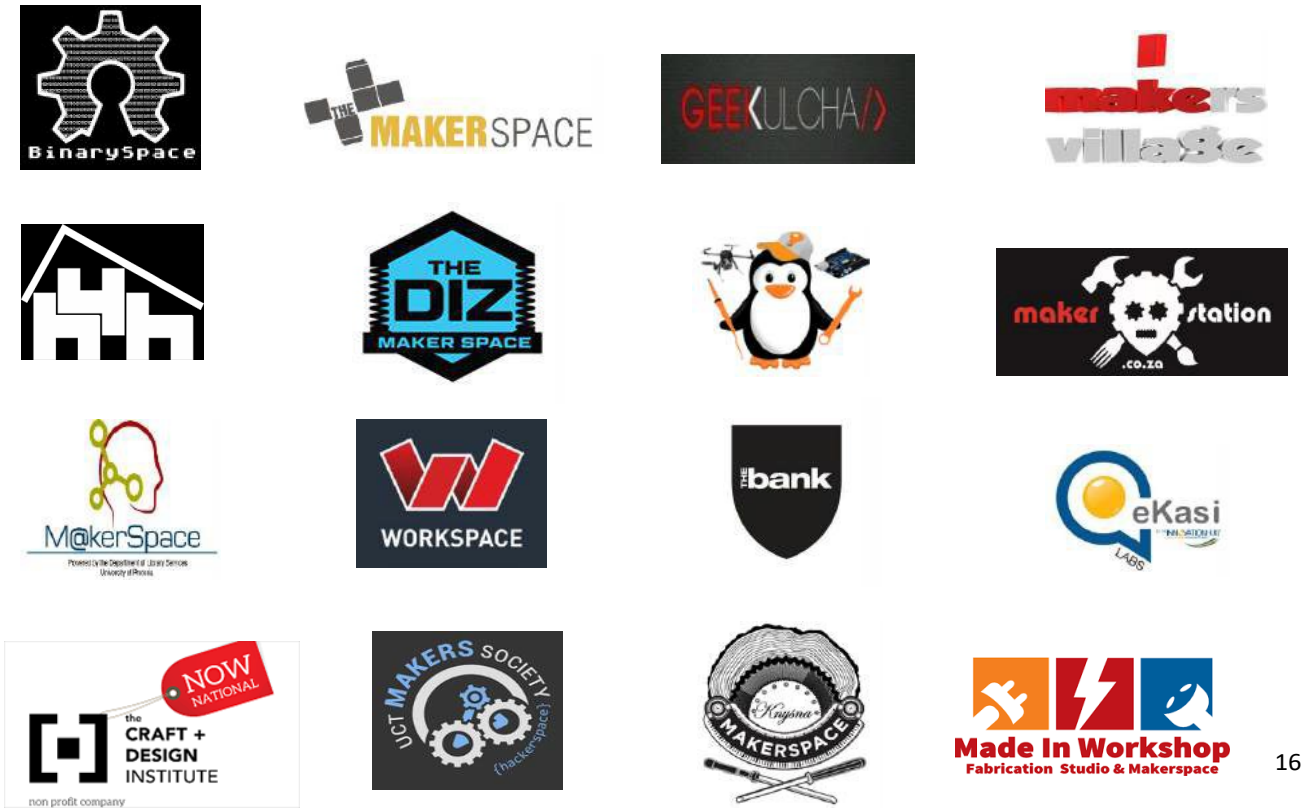
understanding, institutionalisation manifests itself via one or more of the following: formalisation of a maker community's practices (e.g., via membership fees, space rental fees, fee-based training offerings); embedding of a maker community in a fully formalised entity; and/or partnerships between a maker community and a fully formalised entity. Institutionalisation is, in a way, the scaling up of formality.

We noted an apparent trend towards institutionalisation in the South African maker movement. In the early days of the movement, the majority of the spaces were largely non-institutionalised. For example, in Gauteng the pioneering maker collective, House4Hack, was, and remains to this day, a predominantly non-institutionalised space, and two of the other early Gauteng communities, BinarySpace and Makerlabs, were also established as largely non-institutionalised spaces and remain so today. We return to this theme of institutionalisation later in the paper.

We found that South Africa's maker communities are following a wide variety of models to generate funding and/or in-kind support for their activities. Sources of funding and support include member donations, membership fees, fees from course offerings, fees for events, space rental fees, income from linked commercial activities, sales of consumables, government funding/support, university funding/support, combined university-government-industry funding/support via tech hubs, and project-based partnerships with governments (foreign, national, provincial, local), schools, universities, and corporates.

We also found that the maker communities' funding and revenue models link, directly or indirectly, to branding and marketing activities. Most of the communities have an active online presence, via dedicated websites and/or use of social media, and most have developed logos as part of their branding efforts. Figure 2 below shows logos adopted by several of the collectives.

Figure 2: South African Maker Communities' Logos



B. Spatial Variables

Table 4 below provides an overview of the data we were able to collect in respect of spatial variables. (We do not include maker communities for which only online data were collected without follow-up communication).

Table 4: Spatial Variables

Maker Community	Municipality/ city/town	Locality(ies)	Premises	Layout
House4Hack	Tshwane	Centurion	private home	multiple rooms
BinarySpace	Vanderbijlpark	Central	private home	open single-room workspace
Tinker Space	Johannesburg	Milpark	university tech hub	single-room open workspace, next to building providing advanced prototyping support
Makerlabs	Johannesburg	Randburg	private-commercial	open single-room workspace
Geekulcha Makers	Tshwane	Lynnwood, Pretoria	offices at government Innovation Hub, with frequent events at other sites	multiple rooms with cubicles, ad hoc workspaces at other sites
Sebokeng FabLab	Emfuleni	Sebokeng	university tech hub	two open workspace rooms, in same building as computer training room
Digital Innovation Zone (DIZ) Maker Space	Johannesburg	Braamfontein	university tech hub	open single-room workspace, in building containing several meeting rooms and hot desks for start-ups
University of Pretoria (UP) MakerSpace	Tshwane	Hatfield, Pretoria	university campus	open single-room workspace
eKasi Lab Ga-Rankuwa	Tshwane	Ga-Rankuwa, Pretoria North	government community centre	open single-room workspace, in enterprise development support centre with other rooms for computing, training, meetings
I Make Makers Lab	Tshwane	Irene	commercial craft village, with mobile unit	multiple buildings, rooms, workstations

Made In Workshop	Johannesburg	Randburg	private-commercial industrial	large open single-room workspace
eKasi Lab Soweto	Johannesburg	Soweto	government community centre	single-room open workspace, in enterprise development support centre with other rooms for computing, training, meetings
Kluyts MakerSpace	Knysna	Knysna	private-non-profit industrial	multiple rooms, workstations, cubicles
Craft & Design Institute (CDI) Product Support Space	Cape Town	City Bowl	government	multiple rooms, workstations, cubicles, broadly divided into a design area and a workshop area
Workspace	Cape Town	Hout Bay	private-non-profit industrial	multiple rooms, workstations, cubicles
The Bank	Cape Town	City Bowl	private-commercial	open single-room workspace
Maker Station	Cape Town	Woodstock, Southern Suburbs	private-commercial industrial	multiple rooms, workstations, cubicles
Modern Alchemists, Women in Tech Cape Town, Arduino Cape Town	Cape Town	City Bowl	private-commercial (KATO Technology) with frequent events at other sites	office workstations, ad hoc workspaces at other sites
University of Cape Town (UCT) Maker Society	Cape Town	Rondebosch	university campus	ad hoc workspaces on campus
The MakerSpace	Durban	Berea	private-commercial industrial	large open single-room workspace
Bloemfontein FabLab	Bloemfontein	Central	university tech hub	open single-room workspace, in same building as "idea generator" meeting rooms

As alluded to above, we found "locality(ies)" to be one of the most significant variables in the spatial variables category. Even though South Africa's apartheid "separate development" policies, laws, and regulations came to an end in the early to mid-1990s, there can be no disputing that South African cities are still characterised, to greater or lesser degrees, by spatial segregation of the population

along so-called "race" lines. But at the same time, we do not wish to over-particularise the South African case, as the reality is that all the world's cities have characteristics that can to some extent be spatially demarcated, particularly in terms of household income, and South Africa's are, too, arguably evolving towards spatial demarcations characterised primarily by income level. And there can be little doubt that in South African cities, as in all cities of the world, the degree to which an urban conglomeration's various localities are served by low-cost public transportation can also generate significant differences that can be mapped in spatial terms.

Given the maker movement's pronounced collectivist, collaborative, community-building ideals, it would seem to logically follow that the "racial", household income, and public-transport-accessibility profiles, among others, of the locality(ies) where a maker community meets and/or conducts its outreach, could be highly significant. For instance, it would seem to logically follow that the eKasi Lab Ga-Rankuwa maker community in a predominantly low-income, and somewhat remote (in public transport terms, from Pretoria) community will have different dynamics to those of the House4Hack maker community in the largely middle-class suburb of Centurion next to Pretoria, or those of the University of Pretoria (UP) MakerSpace on a well-resourced university campus in the central Pretoria suburb of Hatfield.

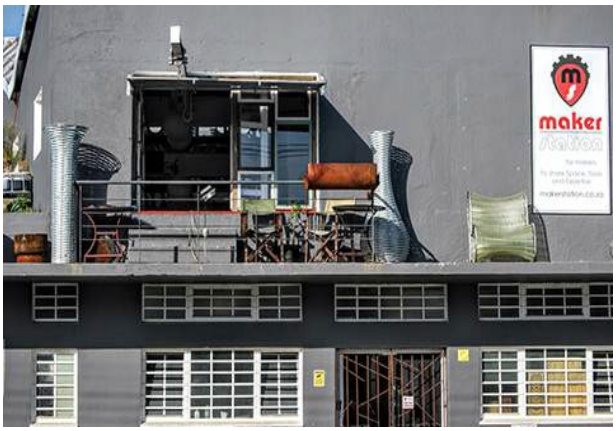
Indeed, we found differences across these three maker communities that can to some extent (but of course not exclusively) be explained by locality. For instance, the "funding and revenue model" variable (one of the management variables outlined in Table 3), is almost certainly dictated to a great extent by locality. The Ga-Rankuwa eKasi Lab is entirely government-funded—a virtual necessity for the establishment of a maker collective in an under-resourced community such as Ga-Rankuwa. Meanwhile, House4Hack, in comparatively well-resourced Centurion, is sustained to a great extent by contributions from its members—including its premises, which is a private home made available to the collective by one of its founding members. And the UP MakerSpace is sustained almost entirely by the funds of the well-resourced university of which it is part. It was not only in the Tshwane Municipality (i.e., the municipality that includes Ga-Rankuwa, Centurion and Pretoria) that locality appeared to be a highly significant variable.

Also significant to each maker community's character is the nature its premises. We found a wide range of premises in use by the communities, including private homes, private-commercial business premises, non-profit premises co-located with private-commercial premises, government-owned/run centres, university-owned/run on-campus premises, and university-owned/run premises within multistakeholder tech hubs. Several of the communities also conduct activities away from their core premises. Notable examples of such outreach are the work of Geekulcha and of I Make Makers Lab. In the case of Geekulcha, while its headquarters are in the government-owned/run Innovation Hub, many of its activities take place away from the Innovation Hub, at the premises of Geekulcha's partners (e.g., schools, NGOs, and local, provincial and national government entities). The I Make maker community uses its mobile unit to offer temporary premises to the remote collectives of artisans the project collaborates with.

Figure 3: South African Maker Community Premises

Workspace, Cape Town

Bloemfontein FabLab



Maker Station, Cape Town

I Make Makers Lab mobile unit, Irene

eKasi Lab Soweto, Johannesburg

eKasi Lab Ga-Rankuwa

We also found a wide range of layouts at the premises used by the maker communities. While several communities work out of single rooms, the majority have multiple-room layouts. Across both the single-room and multiple-room layouts, we found frequent instances of open workspace set-ups, i.e., communal tables and workspaces maximising opportunities for interaction and collaboration among participants.

For other communities, we found the layout of their premises more partitioned, either via the presence of partitions within a single room or via differentiation of uses/users between rooms—and with, in some cases, users paying for use of a particular partitioned space or room.

Figure 4: Interiors of Maker Community Premises

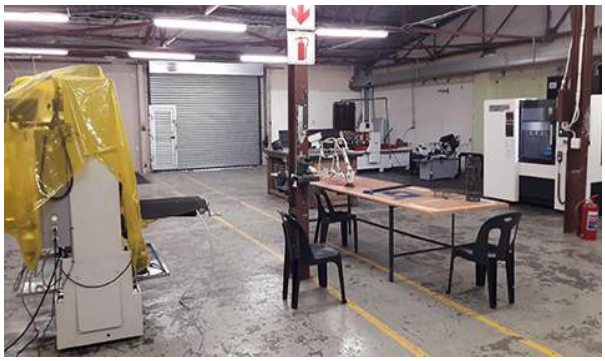
House4Hack, Centurion

Photo credit: The MakerSpace

The MakerSpace, Durban

DIZ Maker Space, Johannesburg

UP MakerSpace, Pretoria



Made In Workshop, Johannesburg

Maker Station, Cape Town

C. Activity Variables

Table 5 below provides an overview of the data we were able to collect in respect of activity variables. (We do not include maker communities for which only online data were collected without follow-up communication.)

Table 5: Activity Variables

Maker Community	Core Tools and Equipment	Core Participants	Core Skills Development Focus Areas	Core Events and Activities
House4Hack	3D printers, laser cutters, CNC machines, microcontrollers, circuit boards	hobbyists	Arduino, Raspberry Pi, 3D computer-aided design (CAD), 3D-printing, basic electronics, internet of things (IoT), soldering	weekly meetups, training academy, competitions, exhibitions
BinarySpace	3D printers, laser cutters, CNC machines, microcontrollers, circuit boards	hobbyists	robotics, printed circuit board (PCB) design, 3D CAD, 3D-printing	weekly meetups, competitions, exhibitions
Tinker Space	3D printers, welding equipment	entrepreneurs	prototyping	support for university tech hub's enterprise development programmes
Makerlabs	3D printer, soldering station, CNC machine, reflow oven, microcontrollers, circuit boards	hobbyists	3D-printing, robotics, antenna-building	weekly meetups
Geekulcha Makers	microcontrollers, circuit boards, sensors	youth	IoT	hackathons, high school student vacation work (VacWork) programmes, weekly meetups at IBM Research Lab, Johannesburg
Sebokeng FabLab	3D printers, laser cutters, CNC machines	university students, general public	3D CAD, 3D-printing, prototyping	university student and general public drop-ins
Digital Innovation Zone (DIZ) Maker Space	3D printers	entrepreneurs, university students	3D CAD, 3D-printing, robotics, prototyping	prototyping support for entrepreneurs, introductions to making for university students, hackathons, exhibitions

University of Pretoria (UP) MakerSpace	3D printers, circuit boards	university students	3D CAD, 3D-printing, prototyping	student prototyping support (e.g., Engineering students), student competitions
eKasi Lab Ga-Rankuwa	3D printers, laser cutter	entrepreneurs	3D CAD, 3D-printing, prototyping	business development, prototyping
I Make Makers Lab	3D printers, laser cutters, CNC machines, woodworking tools, metalworking tools, sewing and embroidery tools, ceramics tools	artisans, craftspeople, entrepreneurs	digitally-mediated arts and crafts production, entrepreneurship	business development, training, rural outreach via mobile unit
Made In Workshop	3D printers, CNC plasma cutter, welding machines (MIG, TIG and spot), knee mill, metal lathe, laser cutter, hand tools	hobbyists, entrepreneurs	prototyping	prototyping support for entrepreneurs
eKasi Lab Soweto	3D printer, laser cutter	entrepreneurs	prototyping	competitions, business development, prototyping
Kluyts MakerSpace	woodworking tools, laser cutters, CNC machines, engineering equipment, craft tools	artisans, product producers, entrepreneurs	woodworking	business development, training, market access opportunities
Craft and Design Institute (CDI) Product Support Space	3D printer, laser cutter, CNC machine, woodworking tools, metalworking tools, moulding tools, sewing and embroidery tools	creative businesses, designers, craft producers, hobbyists, students, general public	digitally-mediated arts and crafts production, entrepreneurship, enterprise development, human capital development	design support, product support (including testing, prototyping), market support, business support
Workspace	3D printer, laser cutter, CNC machine, woodworking tools, metalworking tools, leatherworking tools, sewing and embroidery tools, screen-printing tools, ceramics tools, automotive tools, cooking tools	youth, artisans, craftspeople, entrepreneurs	core skills for employability, entrepreneurship	The Employable Nation (TEN) project targeting unemployed youth
The Bank	3D printer, crafting tools	designers	business development	exhibitions, seminars, workshops

Maker Station	3D printer, laser cutter, CNC machine, woodworking tools, metalworking tools, leatherworking tools, moulding tools, sewing tools, automotive tools	artisans, craftspeople, designers, entrepreneurs	peer-to-peer learning across all maker skill areas (no formalised training offerings)	hosting of short-term and long-term (tenant) members, workshops, custom manufacture, prototyping
Modern Alchemists. Women in Tech Cape Town, Arduino Cape Town	microcontrollers, circuit boards, sensors	general public, women and girls, artists, engineers, developers, entrepreneurs, startups, companies	electronics, robotics, coding, IoT, product development, entrepreneurship, enterprise development	meetups, workshops, hackathons
University of Cape Town (UCT) Maker Society	3D printer, circuit boards	university students	engineering	competitions, technical training
The MakerSpace	3D printers, laser cutters, CNC machines, circuit boards, woodworking tools, welding tools, leatherworking tools	general public, students, hobbyists, entrepreneurs, corporates	prototyping, entrepreneurship, maker skills mentoring/training	weekly meetups, exhibitions, mentorship programmes, hackathons, incubation, co-working, corporate innovation training
Bloemfontein FabLab	3D printers, laser cutters, CNC machine, circuit boards woodworking tools, metalworking tools	university students, general public	prototyping, production	university student and general public drop-ins

The link we suggested above, between the "locality(ies)" spatial variable and activity variables, was noted in respect of how a collective's locality or localities interlink(s) with the data for all four of the collective's activity variables, i.e., its (1) tools and equipment, (2) participants, (3) skills development focus areas, and (4) events and activities. We found that one of the strongest examples of these kinds of linkages was offered by the Kluyts MakerSpace in the Western Cape town of Knysna. One of Knysna's core traditional sources of livelihood was, until recent years, furniture-making with wood from the abundant indigenous forestland of the area, but that industry went into decline. The Kluyts MakerSpace is part of a revived furniture-making operation, with the makers in this case being small-scale woodworkers and furniture-makers who rent workspaces in the MakerSpace from which they can operate their own small enterprises serving their own clients—while at the same time producing for clients of the Kluyts furniture factory. The maker community's tools, participants, skills development, events and activities thus all link directly to the locality.

Another strong example of locality influencing a maker community's tools, participant profile, skills focus and events/activities is Workspace in Hout Bay, next to Cape Town. The Hout Bay area includes

informal settlements characterised by high levels of poverty and unemployment, and, accordingly, one of Workspace's core programmes is called The Employable Nation (TEN). This programme is focused on building a set of 10 skills seen as necessary to increase the likelihood of local youth securing employment: (1) sewing, (2) shoe-making, (3) woodwork, (4) welding, (5) jewellery-making, (6) personal-brand-building, (7) knitting, (8) screen-printing, (9) felting, and (10) bread-baking.

Also demonstrating the links between a maker community's locality and its participants, tools, skills focus and its events/activities is the work of the I Make Makers Lab's mobile unit. Headquartered at the Makers Village in Irene, next to Pretoria, the I Make Makers Lab initiative uses its mobile unit to link up with rural craftspeople in Limpopo, Mpumalanga and KwaZulu-Natal Provinces, including crafters who make items for sale to tourists travelling to and from safaris in Kruger National Park. I Make is seeking to give the crafters the opportunity to enhance their products, and/to enhance their production processes, through use of the equipment in the mobile unit, including 3D printers, laser cutters, and embroidery machines.

In other cases, while the collective's premises are not situated in a low-income neighborhood, the collective is able to leverage proximity to public transit to connect with low-income participants. For example, the Digital Innovation Zone (DIZ) Maker Space, situated within the University of Witwatersrand (Wits) Tshimologong Digital Innovation Precinct in Braamfontein, central Johannesburg, draws in users from Johannesburg's townships, partly due it its close proximity to the Park Station transport hub served by several rail and bus lines. And Cape Town's Maker Station, in the Woodstock neighborhood, benefits from its proximity to Woodstock train station and the large number of minibus taxis routes that include Woodstock when traversing between low-income Cape Flats neighborhoods and Cape Town City Centre.

In general across the four activity variables—(1) tools and equipment, (2) participants, (3) skills development focus areas, (4) events and activities—we found more commonalities than differences among the maker communities covered by the scan. But one significant delineation we were able to note was in respect to orientation towards fabrication, with there being two kinds of orientations, as follows:

- communities oriented primarily towards digitally-enabled fabrication; and
- communities oriented towards both digitally-enabled fabrication and more traditional modes of fabrication such as woodworking, metalworking, leatherworking, fabric/textile-working, fabrication with plastics, jewellery, various arts and crafts, and even, in one case, cooking.

These two categories can be discerned when one looks at the "core tools and equipment" and "core participants" data in Table 5. Within the second category—the communities oriented towards both digitally-enabled and more traditional modes of fabrication—we found there are some with a particularly strong focus on traditional fabrication: the I Make Makers Lab (Irene, Tshwane), the Craft and Design Institute (CDI), Maker Station (Woodstock, Cape Town), Workspace (Hout Bay, Cape Town), and Kluyts MakerSpace (Knysna).

I Make is based at the Irene Makers Village, where artisans create a range of jewellery, arts and crafts, and household items using wood, metal, plastic, glass, ceramics and textiles. The CDI also serves a diverse community of creators and artisans working across a range of materials. The Maker Station caters for, among other things, creation of wooden structures and even fixing motorbikes. As outlined

above, Workspace provides access to tools needed to support provision of a variety of skills (many of them non-digitally-enabled) in its TEN programme. And the Kluyts MakerSpace in Knysna, twinned as it is with a furniture-making factory, needs to provide its artisans with access to traditional woodworking tools.

IV. Analysis and Conclusions

Open AIR's research with maker communities across Africa is contributing to better understanding of how openness and collaboration can help scale up innovation, and can lead to more inclusive sharing of benefits.

It is our sense that South African maker communities are in the early stages of pursuit of a version of scalability that is broader than the traditional notion of scaling as being a function of turning an innovative idea into a commercial business. We detect a quest for a broader notion of scaling, along the lines of "scaling of socioeconomic benefit", which makes room for scaling of innovations into commercial enterprises, but is also interested in scaling of—in the course of pursuit of innovation—skills, educational achievement, gender empowerment, and other benefits without clear commercial elements.

We are also of the view that pursuit of narrow, traditional versions of scaling—e.g., scaling of innovations into businesses, or scaling of maker communities themselves into businesses—may run counter to the current strengths of the South African movement. Pursuit of a narrow notion of scaling by South African maker communities could, in our analysis, undermine sustainability in some cases, as it may lead to pursuit of winner-take-all outcomes that are the opposite of the inclusive, equitable benefit-sharing that appears to be at the core of the current ethos of the South African maker movement.

We return to the notion of scalability in the final "Next Steps" section of this paper. In this section, our analysis is centered on the broader notion of sustainability (which can include, but is much more than, a quest for scale) and the extent to which South Africa's maker communities are moving towards sustainability. By "sustainable", we do not merely mean: are they able to balance their books? Financial sustainability is but one of several interlocking sustainability elements one must consider. The concept of sustainability, which has some of its strongest early origins in the field of environmental protection (see Brundtland Commission (1987), is today applied in myriad contexts and fashions. Contemporary conceptions of sustainability take into account economic/financial, societal/social and environmental/ecosystem elements.

In the sub-sections that follow, we consider what the data from our national scan potentially tell us about South African maker communities' current strengths and challenges in respect of dimensions that we feel can be understood as contributing to, or reflecting, sustainability—with sustainability understood in the aforementioned manner as a fusion of economic/financial, societal/social, and environmental/ecosystem dimensions.

A. Stability of Funding and Revenue Model

In the earlier Table 3 outlining the data we collected in terms of South African maker communities' *management* variables, we saw that in respect of the "funding and revenue model" variable, South

African maker communities are at present following a wide variety of models to generate funding and/or in-kind support, including: donations, membership fees, course delivery fees, space rental fees, twinning with commercial enterprises, government funding/in-kind support, university funding/in-kind support, university-government-industry funding/in-kind support (via a tech hub), and activity-based partnerships with governments (foreign, national, provincial, local), universities, and the private sector.

It can be assumed that communities possessing stable sources of funding and/or in-kind support will have greater chances of long-term survival and vibrancy than those communities without such stability. A key means of building stability in respect of funding and revenues is, in our analysis, diversification of sources. We found evidence, as outlined in Table 3 above, that several of the communities have succeeded in achieving significant diversity in the sources of funding/in-kind support, which augurs well for their future.

Another contributor to funding and revenue stability will be the ability of South African maker communities to develop niches, positive reputations, and positive brands.

B. Establishment of Niches, Reputations and Brands

We found many commonalities across the communities in their attitudes towards, and adherence to, core maker principles such as DIY, learning-by-doing, open innovation, collaboration, skill-sharing, and skills development (see Kraemer-Mbula & Armstrong (2017) for in-depth analysis of these dimensions across eight maker communities in Gauteng Province). But at the same time, we saw significant diversity across the kinds of niche offerings the spaces are seeking to develop.

Examples of niche offerings that we identified are: the focus of the Kluyts MakerSpace on the woodworking and furniture-making enterprises and skills historically found in Knysna; Workspace's The Employable Nation (TEN) focus on skills relevant to the large number of impoverished, unemployed youth in the Hout Bay area; the I Make Makers Lab focus on informal-sector art and craft artisans in remote rural communities; Geekulcha's focused programmes for girls and women (Raeketsetsa), schoolchildren (Future GeekStars), and skateboarding enthusiasts (SkateHacks); The MakerSpace's annual MakerCon Maker Fairs in Durban; and KATO's Women in Tech Cape Town programme. These communities, and several others, also appear to have been able to establish, via the uniqueness of their offerings and the public and media attention their offerings have managed to garner, quite strong reputations and brands. Another strong reputation/brand is that which has been established by the House4Hack collective—a reputation/brand established, in our analysis, via its reputation as: (1) a pioneering, founding makerspace in South Africa; (2) the origin of some of the country's best-known makers and maker innovations; and (3) a fun-loving group of hobbyists always ready to participate in competitions and collective events. The House4Hack offshoot BinarySpace seems to have a similar brand. Other communities found to have strong brands at the time of the research were, in Cape Town, the Craft and Design Institute (CDI), Maker Station, Modern Alchemists, Arduino Cape Town; and, in Gauteng, the DIZ Maker Space, the University of Pretoria (UP) MakerSpace, Made In Workshop, and the eKasi Labs programme; and in Bloemfontein, the Bloemfontein FabLab.

Communities able to establish well-known niche offerings, and strong positive reputations and brands, can be expected to have increased chances of sustainability, as they will be able to leverage their niches, reputations and brands to attract participants, partners, and funding/in-kind support.

C. Knowledge Appropriation and Intellectual Property (IP)

In respect of management of knowledge and innovation, the relationship between open models and proprietary models is not binary. Previous Open AIR research has found that, in African innovation settings, collaborative, openness-oriented dynamics predominate, and formalised knowledge appropriation is often not suitable to such contexts (De Beer et al., 2014). Other research by Open AIR and the World Intellectual Property Organisation has found that the relationships between open innovation and knowledge appropriation are especially varied in the informal sectors that predominate in Africa (De Beer et al., 2014, 2016; De Beer & Armstrong, 2015; De Beer & Wunsch-Vincent, 2016; De Beer et al., 2016; Kraemer-Mbula, 2016; Kraemer-Mbula & Wunsch- Vincent, 2016).

In-depth interviews with participants in Gauteng maker communities found that the vast majority of the interviewees favoured open over proprietary management of knowledge and innovation (see Kraemer-Mbula & Armstrong, 2017). Nevertheless, there are at least three dimensions of knowledge appropriation that are likely to require careful management by South Africa's maker communities: (1) appropriation of a community's naming, logo and other brand features, which can be subject to copyrights and trademarks; (2) appropriation of the innovations and creative outputs of community participants, which can be subject to patents, copyrights, and trademarks; and (3) maker community management of potential liability for IP infringements by participants making use of community facilities.

In respect of the first dimension—naming, logos, and brand design elements—South Africa's maker communities will need to be cognizant of the fact that, if and when the number of maker communities becomes more numerous, rivalries could develop that could result in IP disputes in relation to similarities between names, logos and branding design. We did not, in the course of our research, detect any such rivalries presently in existence, and IP disputes would certainly seem to run counter to the generalised adherence to principles of open knowledge exchange in the sector. Thus, in our analysis, IP disputes at the level of communities' naming, logos, and other branding elements are imaginable but unlikely, at least in the short-term, in this sector.

The second appropriation dimension—management of rights to use of innovations and creative outputs produced by community participants—is another dimension of which the South Africa's maker communities must remain aware. We found ample awareness of this dimension in our in-depth interviews with Gauteng maker community participants, and the overwhelming consensus among interviewees was that makers should freely exchange skills and ideas, and that pursuit of formalised IP rights—e.g., pursuit of a patent in an invention—should not be a focus of maker activity. The focus, according to almost all the Gauteng interviewees, should be on open collaboration, and such collaboration would not be fully possible if participants demanded, for instance, the signing of non-disclosure agreements before sharing their ideas with others (see Kraemer-Mbula & Armstrong, 2017). Of the more than 20 interviewees across eight Gauteng maker communities interviewed by Kraemer-Mbula and Armstrong (2017), only one was pursuing a patent in his innovation.

Nevertheless, South Africa's maker communities may, as they become more established, find it increasingly difficult to maintain their current ethos of open, non-appropriation-oriented approaches to innovation. The communities that are likely to be particularly vulnerable to tensions over IP ownership are those fully embedded or partially embedded in fully formalised institutions, e.g., the communities embedded in universities, in university/government/industry tech hubs, and in government facilities.

The third knowledge appropriation dimension requiring vigilance—potential liability for IP infringements—is also likely to be particularly relevant to those maker communities embedded in fully formalised institutions, e.g., universities, tech hubs, or government facilities. One of the most popular maker technologies, 3D printing, has potentially far-reaching secondary liability issues. For example, if a student in a university-run maker community downloads an IP-protected design, prints it, and commercially gains from it, might both the student maker and the university be liable for IP infringement? If yes, then institutionally embedded or partially institutionally embedded maker communities may find themselves, in the future, coming up against institutional policies and regulations limiting the free and open ethos that is so dear to makers.

Knowledge appropriation is, of course, but one of several elements that can potentially be influenced by a maker community's degree of institutionalisation. And institutionalisation is not merely a matter of a collective's embeddedness, or lack thereof, in a fully formalised entity. As the next sub-section points out, institutionalisation also operates at the levels of practice, and via partnerships, and all forms of institutionalisation are potentially relevant to the community's vibrancy and viability.

D. Elements and Degrees of Institutionalisation

As mentioned above in the findings section, we identified a trend towards institutionalisation of South Africa's maker communities—with institutionalisation represented, in in our conception, by formalisation of maker communities' practices; embedding of maker communities in fully formalised entities; and/or partnerships between maker communities and fully formalised entities. In our analysis, the elements of institutionalisation that we found across the communities are, for the most part, beneficial to the communities and their users. But at the same time, we are of the view that South Africa's communities need to guard against over-institutionalisation, and/or elements of institutionalisation that may limit a collective's reach and/or informal-innovation ethos.

Maker communities embedded in university campuses (e.g., UP MakerSpace, and UCT Maker Society) or embedded in university-driven tech hubs (e.g., DIZ Maker Space, Bloemfontein FabLab, Sebokeng FabLab, and Tinker Space) can benefit a great deal from university financial and in-kind support, and from the ease with which they can serve students. But at the same time, the viability of these spaces is likely to be greatly enhanced by their ability to attract, and serve, makers from *outside* their university student body—and such outreach may be hampered by university rules, regulations and security procedures in respect of non-students/staff/faculty entering, and conducting activities on, campus.

Similarly, maker communities embedded in government structures (e.g., eKasi Lab Ga-Rankuwa, and eKasi Lab Soweto) can certainly benefit from the government funding and in-kind support they

receive, and from the ability to channel participants from and into complementary government initiatives in support of skills development and enterprise development. But similar to the situation for the university-based communities, the government-based communities' long-term viability will likely be determined to a great extent by the degree to which they are able to position themselves, in the populations they serve, as not merely agents of the structures in which they are embedded (i.e., state structures) but rather as community-driven, community-accessible entities.

We found the case of Geekulcha instructive of how institutional-embeddedness can be optimally managed. While the collective is headquartered at the fully formalised, Gauteng Provincial Government-supported Innovation Hub in Pretoria, the majority of Geekulcha activities and programmes are run at locations, and with partners, outside the Innovation Hub, in cooperation with universities, schools, the private sector, and governments of all levels (foreign, national, provincial, and local).

Another important balancing act that, in our analysis, elements of institutionalisation require of maker communities is maintenance of a balance between institutional dynamics and the informal-innovation dynamics that are central to making. Drawing on the conceptualisations outlined in De Beer et al. (2016) and Kraemer-Mbula (2016), we regard the key modes of informal innovation as the following: (1) constraint-based innovation; (2) incremental innovation; (3) collaborative innovation; (4) informal approaches to knowledge appropriation; and (5) innovation in informal networks/communities in informal settings. We see both potential tensions and potential synergies between institutionalisation and informal innovation in the South African maker context.

We found evidence in the data that there is at present a strong spirit of informal innovation across South African maker communities, with most of the communities, including the relatively institutionalised ones, actively seeking to preserve the movement's emphasis on informal-innovation modalities. Thus, it would appear that, at the present moment, elements of institutionalisation are proving to be largely synergistic with, rather than undermining of, the ethos of informal innovation in South Africa's maker communities, allowing the communities to play an intermediary "semi-formal" role, mediating flows of formal and informal modes of innovation. This phenomenon of semi-formal mediation is one already observed by our Open AIR colleague Kawooya in his research into the workings of the informal sector in the Ugandan capital Kampala (Kawooya, 2014).

E. Robustness of Communities of Practice

As stated at the beginning of this paper, Open AIR views maker communities as examples of "communities of practice" as conceptualised by Wenger (1998) and Wenger et al. (2002). In the words of Wenger et al. (2002):

> Communities of practice are groups of people who share a concern, a set of problems, or a passion about a topic, and who deepen their knowledge and expertise in this area by interacting on an ongoing basis. (Wenger et al., 2002, p. 4)

Wenger et al. (2002) offer "seven principles" of "community design" that they argue are integral to a successful community of practice, as follows:

1. Design for evolution.
2. Open a dialogue between inside and outside perspectives.
3. Invite different levels of participation.
4. Develop both public and private community spaces.
5. Focus on value.
6. Combine familiarity and excitement.
7. Create a rhythm for the community. (Wenger et al. 2002, p. 51)

It would be unrealistic to expect most of South Africa's maker communities, given their relatively recent establishment, to exhibit evidence of all seven of these principles—and it is also, of course, arguable whether all seven of these dimensions are necessary, as the Wenger et al. (2002) principles are merely a proposed framework, and a fluid one at that. Nevertheless, in analysing our national scan data we found evidence among South Africa's maker communities, to varying degrees, of all seven of the objectives implied by the Wenger et al. (2002) principles. In particular, we found multiple instances of adherence to the first three principles, i.e., instances of communities engaged in what amounted to "design for evolution"; widespread acknowledgement among the spaces of the need to remain open to "outside perspectives"; and widespread desire to achieve a multitude of "levels of participation". We also found frequent instances of explicit or implicit focus on the final two Wenger et al. (2002) principles: the principles of providing both "familiarity and excitement" and of creating "a rhythm for the community", e.g., via weekly meetups and/or frequent events.

F. Embeddedness in Broader Networks

Each individual South African maker community seeks to stir local imagination, to allow local people to come together in an environment that supports making for education, hobby, innovation, employment, and more, i.e., to participate in a localised, largely non-virtual, community of practice. But at the same time, it seems clear that South Africa's individual maker communities can benefit greatly from being embedded in additional, non-localised communities of practice at regional/provincial, national and international levels, animated chiefly by online collaborations enabled by Internet-based information and communication technology (ICT) platforms.

At the March 2017 South African Maker Movement Workshop convened by Open AIR in Pretoria, we found significant interest among the South African makers present in how individual South African maker communities can benefit from networking, both virtually and non-virtually, beyond their localities. We observed consensus at the workshop that at regional/provincial level, communities could work together on larger projects for which one makerspace alone might lack the necessary resources. And indeed there were examples of such collaborations in both 2016 and 2017, with maker coalitions in Gauteng Province, the Greater Cape Town area and Durban coming together to jointly participate events: Decorex design shows in Johannesburg, Cape Town and Durban in 2016; and the 2016 and 2017 Wits Fak'ugesi digital innovation festivals in Johannesburg.

We also found evidence of an emerging desire among many South African makers to formalise themselves to some extent at a national level via an association. The proposed structure, which began to take shape in early 2016, is being called "the South African Maker Collective". The

Collective has to date been spearheaded by Durban's The MakerSpace, which, among other things, convenes annual MakerCon showcase events. The Collective made both verbal and video presentations at Open AIR's workshop, and also facilitated the workshop breakaway sessions aimed at generating ideas for how the South African movement could operate at local, provincial, national and international levels. Later the same month, the Collective sent out an email message to all workshop attendees, asking attendees to: give inputs on a written record of the meeting's outcomes; provide information about their work; and consider formalising their membership in the Collective. That email stated that

> [w]e are excited to get The South African Maker Collective up and running more formally. […] The idea of the collective is to minimize admin on makers while maximising their impact, influence and access to resources. (South African Maker Collective, 2017)

We also found evidence of networking by some of the South African maker communities with makers elsewhere in African and internationally. For example, the founder of the non-profit foundation that runs the I Make Makers Lab project told us that I Make based some its approaches on lessons learned in working with makerspaces in India, Ghana, and the Netherlands. Geekulcha was found to be collaborating on some of its programmes with entities in Mozambique, Kenya and Botswana. (One of the entrepreneurs we interviewed at eKasi Lab Ga-Rankuwa said he had received useful collaborative support from Mozambican innovators, via a Geekulcha event at the Innovation Hub, in the course of developing his enterprise idea.)

In addition, the participation by several of the South African maker communities (as detailed in the tables above) in the UK-driven Maker Library Network (MLN) was providing the communities contact with makers from elsewhere in Africa (e.g., Nigeria) and outside the continent. Indeed, at the time of our March 2017 workshop, the founders of The MakerSpace in Durban and Workspace in Hout Bay were both in the UK for an international maker event. Other examples we found of international connections were: one Makerlabs participant's exposure to maker activities in Kenya, and another Makerlabs member's time spent at a makerspace in Nottingham, UK. And it was found that one of the drivers of the South African Maker Collective's participation in Decorex SA 2016 and Wits Fak'ugesi 2016 received her initial exposure to maker activities during a period of work as a designer in London.

In our analysis, embeddedness in sub-national, national, continental, and international networked communities of practice can be potentially significant contributors to the viability of South African maker communities. As part of our action research orientation, we in the Open AIR network are making efforts to facilitate some of the offline and online interactions that such communities of practice require. Of particular interest to Open AIR, as a continental project, is the degree to which an African maker community of practice, perhaps with sub-sets of English-, French- Portuguese-, and Arabic-speaking makers, will emerge.

As part of that networking, our March 2017 workshop in Pretoria included not only South African makers and researchers but also Open AIR researchers from Egypt, Nigeria, Ghana, Ethiopia, and Kenya. The aim was not only to help the Open AIR researchers in those other countries to acquire enhanced continental context for their national studies, but also to engender knowledge and idea-sharing across countries. Among the positive outcomes from these interactions was participation

by the founder of South Africa's I Make Makers Lab in an October 2017 workshop hosted by the Open AIR hub in Cairo, the Access to Knowledge for Development Centre (A2K4D) at The American University in Cairo (AUC), on "Collaborative Innovation for Open and Inclusive Development: Data, Maker Spaces, and Mobile Telephony". That workshop brought together makers and researchers from Egypt, South Africa, Kenya, and Canada.

Among the other potential enablers of development of an African maker community of practice is the work of bodies such as Maker Faire Africa, mentioned in the introduction to this paper. Maker Faire Africa bills itself as seeking to "connect up, size up, mash up, and up the [ante] on redefining the future of the world's most promising continent through our own authentic, relentless African ingenuity" (Maker Faire Africa, n.d.).

At the level of the international maker community of practice, which seems clearly to exist in the industrialised world via the work of the aforementioned US-based international Maker Faire movement, Open AIR hopes to contribute to building stronger South-North and South-South dimensions. In 2016-17, Open AIR built African-Canadian linkages between makers and maker-focused researchers via events and activities in Ottawa, Pretoria, Nairobi, Casablanca, and Cairo, and began to forge links to makers and maker-focused researchers in Argentina, Brazil, and other Latin American and Caribbean countries.

In our analysis, South African makers are likely to greatly benefit from participation in multiple networked maker communities of practice, but with the localised communities practice, centered on the local maker space(s), persisting as the most important of the communities of practice in terms of fulfilling the seven principles outlined above from Wenger et al. (2002).

G. Orientations towards Innovation and Enterprise Development

Also important for South African maker communities, in our analysis, is how they position themselves in relation to the dimensions of innovation and enterprise development. We found that all of the South African maker communities we identified are seeking—with varying degrees of explicitness—to be part of innovation-and-enterprise-development ecosystems.

Viewing innovation and enterprise development along a continuum—from idea to innovation, to prototype, to commercialisable product, and finally to scaled, revenue-generating enterprise—we observed that: some of the South African maker communities are focused more towards the innovation end of the continuum, e.g., House4Hack, BinarySpace, and Makerlabs; other communities tend more towards the enterprise development end, e.g., eKasi Lab Ga-Rankuwa, eKasi Lab Soweto, I Make Makers Lab, and Kluyts MakerSpace; the majority of the communities sit somewhere near the middle of the continuum; and all communities sit somewhere on the continuum, i.e., there are none that sit at one of the two extreme ends, catering either exclusively to innovation for its own sake or exclusively to innovation as a means to enterprise development.

While one can justifiably argue that viewing innovation-to-enterprises along a continuum is overly simplistic, we feel this conceptualisation has some descriptive value in helping to understand the orientations of South African maker communities. The picture that emerges, of South Africa's maker communities sprinkled along the continuum—seeking to develop their own niches along the continuum—augurs well, in our analysis, for the South African maker movement. One of the

movement's current core strengths would appear to be its heterogeneity. There are several approaches being attempted, and the ideal, in our analysis, will be if several of the approaches prosper, allowing South African innovators a variety of possible entry points into the continuum between innovation for the sake of it and innovation in service to scaling of an enterprise. (However, as is discussed below in "Next Steps", we are not presently of the view that a narrow focus on scaling of commercial enterprises—i.e., a focus on the "commercial enterprise" extremity of the innovation-to-enterprise continuum—will play to the current strengths of most of South Africa's maker communities.)

Another apparent strength of the South African movement's current heterogeneity is its ability to be inclusive—a particularly important element in a context such as South Africa's with its high levels of unemployment and poverty, its urban-rural and gender divides, and its spatial, social, and economic legacies of racial segregation. Central to the potential long-term viability of the maker movement in South Africa, in our analysis, will be the degree to which its individual maker communities can each, in diverse ways, foster enhanced socioeconomic inclusion, via making, of their participants.

H. Socioeconomic Inclusion

Most of the South African maker communities we identified seek to engage, at least to some extent, with historically disadvantaged people, and to bring such people within the sphere of their communities. Such engagement is typically aimed, in our analysis, at fostering socioeconomic inclusion for these participants, i.e., it is assumed that through engagement with the people, tools and activities available in a maker community, participants will enhance their economic and social circumstances. Enhanced economic opportunities could, for instance, take the form of increased employability as a result of acquisition of new skills in the maker community, or development of a commercial or social enterprise based on an innovation prototyped in the community. The social inclusion element can also have many possible facets. The knowledge that one belongs to a community can in and of itself represent a powerful improvement in a person's life, let alone the transformative power of the interactions the person has with others in the community, both in-person and via virtual means. Indeed, as discussed in other sections of this paper, to be part of a community of practice can be a powerful thing.

We see clear emphasis on socioeconomic inclusion in the work of many of South Africa's maker communities. For example, Kluyts MakerSpace is working with local woodworkers marginalised by the decline in Knysna's furniture-making sector; Workspace's TEN skills-building project is working with unemployed youth living in Hout Bay's impoverished informal settlements; I Make Makers Lab, the Craft and Design Institute (CDI), and Maker Station are working with, among others, under-employed artisans and craftspeople; KATO's Women in Tech Cape Town and Geekulcha's Raeketsetsa project are building participation by girls and women in making; and the DIZ Maker Space, the Soweto and Ga-Rankuwa eKasi Labs, the Sebokeng FabLab, and the Bloemfontein FabLab are working with township-based innovators. The vibrancy and longevity of all of these maker communities will to a great extent depend on their ability to foster the socioeconomic inclusion that they are seeking to achieve.

V. Next Steps

We now outline two core "Next Steps" elements that flow from the research presented in this paper.

A. Continued Interrogation of the Notion of Scalability

The points we made near the end of the preceding section—about the value of the South African maker movement's heterogeneity of approach to the innovation-to-enterprise continuum, and about the importance to the movement of its delivery on socioeconomic inclusion—are what render discussion of scalability complex.

A core complexity arises from how one chooses to understand the term "scaling" in the maker context. We are of the view that the traditional notion, of innovation-scaling being a function of turning an idea into a commercialised enterprise, is too limited for the maker context. In our analysis, several of the South African maker communities appear to be engaged in efforts to develop models that can "scale" socioeconomic inclusion and equity, i.e., the communities appear to be pursuing a notion of innovation-scaling that is broader than merely the hope that certain makers will be able to someday establish commercial enterprises. The notion of scaling, largely implicit rather than explicit, that we sense at present in the South African maker movement is one that has pronounced social and educational dimensions. All the communities appear to be intent on empowerment of one sort of another—of youth, schoolchildren, of girls and women, of the unemployed, of rural people, and of South Africans generally—with not only the economic opportunities that maker skills can offer, but also with the confidence and connectedness that learning and mastering and sharing these skills can provide. This is why we see the dynamic of scaling, in a maker context such as South Africa's, as being a broad "scaling of socioeconomic benefit" dynamic. In our view, it is likely to be the ability to scale in those broader terms that will be central to the sustainability of the movement going forward.

Conversely, as we said at the beginning of the "Analysis and Conclusions" section above, pursuit of narrower notions of scaling—e.g., scaling of individual enterprises, scaling of maker communities themselves—has the potential to undermine the sustainability of a community, because, among other things, smallness and collective spirit are valuable parts of the "scaling of socioeconomic benefit" recipes that most if not all South Africa's maker communities seem to be trying implicitly create, each in their own unique, niched fashions.

Accordingly, we and our Open AIR research network colleagues in other countries are determined, going forward, to interrogate notions of scalability in as flexible a fashion as possible, so as to ensure that potentially valuable data analysis and grounded theory-building are not constrained through a narrow focus on scalability's commercialisation dimensions.

B. Maker Movement Studies in Other Countries

Integral to Open AIR's research with maker communities—in search of an enhanced understanding of interactions among openness, collaboration, innovation-scaling, and sharing of benefits—is an effort to generate comparisons across different national contexts.

Accordingly, Open AIR researchers are investigating the emergence of making not only in South Africa but also in Kenya, Egypt, Tunisia, Morocco, Nigeria, Ethiopia, and Ghana. Work is also underway towards development of studies of making Canada and Latin America. Open AIR is optimistic that valuable findings, in respect of both commonalities and contrasts, will emerge from comparisons of elements that emerge across the national studies.

Open AIR's comparative work across maker movements in various national contexts is, at the most general level, guided by the network's three core research themes: high technology hubs, informal-sector innovation, and Indigenous community entrepreneurship. Maker communities, as collectives where the informal and formal sectors often interact, offer tremendous opportunities to study intersections across these research themes.

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