Fabrication Laboratories: Problems and possibilities of implementation in Latin America.

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Abstract

Since 2007, Latin America has incorporated a set of emerging techniques promoted under three initiatives: a) from the experience of Master and Doctoral students who return to their home countries and promote their experience, b) from the external academic experience that goes towards the region, and c) from self-learning. These experiences are developed in an academic area, unlike Europe or the U.S., where they were promoted from and to professional practice, with varying degrees of implementation and effect. Generally speaking, the academic programs of the region lack a policy of inclusion of systematized emerging technologies, and that produces a slow uptake, especially in architecture. On one hand, if educational policies are not stable, equipment investment cannot be stable, and on the other hand, the generation gap between those who promote and those who accept blends into disruption and status quo. Each implementation in the region produces adverse and complex patterns, replicating existing models and seeking alliances with institutions in developed countries. Thus, there are self-help groups, while others incorporate academic, technical and/or commercial supervisions, in principle through the Center for Bits and Atoms (MIT Fab Lab) and McNeel Associates (Rhino Fab Lab). In this research, we evidence evolution and implementation processes in Latin America of the three types of initiatives, analyzing the case study in Peru, which together open up the possibility of moving from a phase of experimentation, trial and error to another that actually promotes local innovation and inclusion.

Keywords

Fab Lab, South America, MIT, Rhino, Digital Fabrication

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Introducción
Since the beginning of the 21st century, the Fabrication Laboratories have been implemented as innovation and entrepreneurship centers, allies for design and personal fabrication. In developed countries, this process started in the profession (Leach, 2010 and Anderson, 2012) and about the same time in academy (Temkin, 2004; Gershenfeld, 2005; Dempsey and Obuchi, 2010; Self and Walker, 2011) as in mutual coexistence (Barkow, 2008, 91). This phenomenon is caused by the continued cost reduction of the machines, the growth of open source software and hardware (Troxler and Wolf, 2010, Troxler, 2013), and because the cost of a part or component *"is based on the machine's time, not shape or variety of parts, so there is no surcharge for complexity or difference"* (SHoP, 2012, 251). The trend was evident in conferences such as *Non Standard Praxis* (MIT, Cambridge, 2004), *ACADIA Fabrication* (Toronto, 2004), through exhibitions like *Scriptingbypurpose* (Philadelphia, 2007), *Home Delivery: Fabricating the Modern Dwelling* (MoMA, New York, 2008), the *Architectural Biennial Beijing* on emerging technologies (Beijing, 2004-2010) curated by Neil Leach and XuWei-Guo, including events on fabrication organized by the *Center for Bits and Atoms* since 2001. In general, *"for Europeans and Americans the way to high technology has been a steady evolution, so that its adoption was a logic mode to respond to their own circumstances"* (Waisman, 1995, 70), conversely *"for Latin America, high technology was transformed into the symbol of progress and its utilization became a misunderstood sign of an apparent modernity"* (Waisman, 1995, 71). The procedures have been classified and organized into taxonomies that summarize their processes (Iwamoto, 2009; Barkow Leibinger, 2009; Sass, 2010). This is a reflection of patterns and conventions that, in one form or another, are replicated again and again in different parts of the World and Latin America is no exception.

Another facilitating factor of the growth in the region is the reduction of the cost of rapid prototyping technologies to less than US$500, and that coincides with the expiration of some patents. Although there were expired patents, such as *Stereolithography*® (SLA) of *3D Systems* (2004) and *Three-Dimensional Printing*® (3DP) of MIT (2010), its impact was not as significant as the most demanded technologies like FDM of *Stratasys* and SLS of *3D Systems*. In an analysis performed on his blog *Law in the making: The 3D Printing Law Blog*, Paul Banwatt states that *Fused Deposition Modeling*® technology, known by its initials FDM® was patented in 1989 by S. Scott Crump, founder of *Stratasys* and expired in 2009, the same year of the foundation of

Makerbot Industries which uses the same filament extrusion technology. On the other hand, the patent for *Selective Laser Sintering®* technology (SLS) by *3D Systems*, will expire in 2014. If to this we add that *Stratasys* merged with *Objet Ltd.* (December, 2012) and acquired *Makerbot Industries* (June, 2013), we see that market leadership has concentrated on large enterprises, as did Autodesk Inc. in the software industry since the 1990s and now distributes its software for free in the academic system.

In this context, there are two cultural trends that differentiate the implementations between developed and developing countries.

From standardized to custom-made. How long does it take us to find the product that we like? In terms of consumption, two decades ago we found one or two options per product. Today we have hundreds of possibilities available to us. This industry effect was studied by Barry Schwartz under the name of *Paradox of Choice*. It suggests that everyone should be the author of their own life, and have freedom of choice. Piasecki and Hanna (2010) redefine the concept when studying that users are unable to define what constitutes a meaningful choice because they start, in many cases, with an ill-defined problem. The challenge for those who exercise personalized fabrication is not to produce more options, but to make choosing relevant, allowing the user to customize the product instead of choosing from hundreds produced by others. That is, an object in itself can be a variety or series rather than an option, because it takes into account the object as part of a continuum (Cache, 2011, 62).
Companies segment consumers to optimize costs, which results in products which not always respond to specific needs (functional, ergonomic, emotional, etc.). Digital fabrication, in turn, can create highly customized products, as a handicraft method, with the advantages of the industrial system because it optimizes time and cost. In this sense, Gershenfeld showed in his MIT classes *"that the ultimate app for personal fabrication in the developed world is the technology for a market of one."* This is slowly happening in developing countries.
In the Andean region, self-construction occurs in over 70% of the city, i.e. the user builds for himself over a period of time. Although the Peruvian state has social housing programs, these are minimal, because the population has been building without technical assistance since the 1940s, and has produced their housing from a module that grows with the materials allowed by the economic situation. Housing is produced by imitation or referencing, a cultural phenomenon that had occurred also in the workshops for the implementing of emerging technologies conducted between 2006 and 2012, where the repetition and automation prevailed, on programming or customization. In 2010, in visits made by *Fab Lab Lima* to different industries in the city, in order to promote custom fabrication, there were no initiatives to promote adaptations or new machines. On the contrary, industries were interested in acquiring the equipments as they were. The culture is imposed when gradually consuming technology based on previous experience or work in other contexts, without taking risks, resulting in a standardized cycle instead of a customized one.

From consumer (the one who demands) to prosumer (the one who consumes but personalizes their production). While in developed countries personal fabrication and computation are allies in the processes (Gershenfeld, 2005, 8), the developing countries depend on the consumption of a product (or technology) instead of thinking about producing it for ourselves. The initiative of the MIT *Fab Labs* seek to enhance the *creative power* of the people, who, under the conditions of current industrial system, have become passive consumers whose major area of freedom is to decide on the creations that others have pre-established. In this way, freedom is provided to the individuals, while promoting the development of creative communities, regardless of whether they are architects or not, because it is based on cooperation and multidisciplinary work.

Implementation Initiatives in Latin America

We cannot generalize the experiences in South America, because there are local factors that make parallel ways, despite similar political situations that spanned from the 1970s. To differentiate and identify case studies that define geographical areas with similar progress since the twentieth century, we use Bethell's (1991) historical organization: Argentina, Uruguay, Paraguay, Chile (Southern Cone), Peru, Bolivia, Colombia, Ecuador and Venezuela (Andean Region) and Brazil. The implementation process has been developed more intensively (in number) in the Southern Cone and Brazil than in the Andean Region.

The implementation of Fabrication Laboratories in Latin America follows the same pattern identified in other digital technologies (Herrera, 2011), but in a different implementation timeline. Progressively implementations were studied as follows. *Group A*. Experiences of Master and Doctoral students; Group B. External academic/commercial circuit, and Group C. Self-learning.

***Group A*. Experiences of Master and Doctoral students**. Around 2007, several Latin American universities begin to formalize initiatives as part of academic research groups. These experiences did not start with any external oversight, but reflected the experience and results of individuals with Master or Doctoral studies. They continue to direct local Master and Doctoral students in theses that give continuity to said technologies.

Southern Region.

In Brazil, in 2007, Gabriela Celani (PhD at MIT under the guidance of William J. Mitchell / Terry Knight), founded in January the *Laboratório de Automação e Prototipagem para Arquitetura e Construção* (LAPAC) in order to support different areas of engineering and architecture in UNICAMP in fabrication issues. Underlea Bruscato (UPC PhD) who started a laboratory at *Universidade do Vale do Rio dos Sinos, UNISINOS* (Porto Alegre, 2008) now directs another laboratory at *Universidade Federal do Rio Grande do Sul*, *UFRGS*, joined by the Venezuelan Ernesto Bueno (UIC Master) who worked with the Brazilian Affonso Orciuoli (UIC PhD). Affonso prompted several initiatives in Sao Paulo mainly to install fabrication laboratories.

Another initiative promoted in Brazil was forged by scholars gave of the *Sociedad Iberoamericana de Gráfica Digital* (SIGraDi). First on the *Universidade Presbiteriana Mackenzie* (Sao Paulo, 2009) and then in the *Universidade Federal do Ceará* (Fortaleza, 2012). The result led participants to self-learning since it has consolidated concepts. Both groups balance the management for the acquisition of equipment and the teaching through workshops in different seasons a year.

In Chile, Eduardo Lyon (Ph.D. in *GaTech* under the direction of Charles Eastman) prompted the design and digital fabrication in architecture through graduate courses, conferences and workshops that coincided with the X Congress of SIGraDi (Santiago, 2006) at *Universidad de Chile*. Through the management of Pedro Soza (*GaTech* PhD candidate under the guidance of Charles Eastman) the use of technologies was promoted and the *Laboratorio de Prototipado Digital* at FAU (2012) was established. Claudio Labarca, (UCLA Master) starts at *Pontificia Universidad Católica de Chile* in the first half of 2007, the *Taller de Ensamble Digital* in collaboration with Arturo Lyon (AADRL 2007) and Diego Pinochet (MA UC, 2008). Within Chile, there are initiatives at *Universidad Técnica Federico Santa María*, in the *Laboratorio de Materiales y Fabricación Digital, Labomat* (Valparaíso, 2010) promoted by Luis Felipe Gonzalez and currently in chair with Cristian Calvo. There is also the laboratory at *Universidad Mayor* (Temuco, 2010) and Rodrigo Garcias's implementation (UPC PhD) at *Universidad del Bio-Bio* (Concepción, 2008). In 2012, Sergio Araya (MIT PhD) became director of the School of Architecture of *Universidad Adolfo Ibañez* and installed the first *Fab Lab* in Chile.

In Uruguay there is the *Laboratorio de Fabricación Digital Montevideo* (labFabMVD) at *Universidad de la República* (Montevideo, 2011), directed by Marcelo Payssé, member at SIGraDi.

Andean Region

Colombia has incorporated different academic laboratory settings: from centralized in schools to decentralized laboratories. SIGraDi promoted in 2010 workshops at *Universidad Javeriana* (Bogotá, 2010) directed by Pablo Baquero (Columbia University, 2006).

In Colombia there are also graduates from *Instituto de Arquitectura Avanzada de Cataluña* (IaaC). Gabriel Ochoa heads *FabLab* Medellin since 2010 and has conducted workshops with Rodrigo Toledo (IaaC). Fabio Lopez (IaaC), who directs *FabLab Unal Medellín* at the *Universidad Nacional de Colombia* (2013).

The same happens in Peru but through self-management, with the work of Luis Odiaga (IaaC, 2009) through *Artificial Wrong* (AW 2010, 2011) with companies that provide CNC machines.

Between 1997 and 2007, nearly 60 Latin American students have graduated from the *Architectural Association Design Research Laboratory*. Since 2010 the school promotes a worldwide *Visiting School* program, with a series of experiences in the region led by graduates who returned to their home countries for different reasons and who adapt their experience to local situations. Sergio Pineda (AADip 2004) in Medellin and Diego Perez (AADRL 2008) in Bogotá systematically foster London's Architectural Association Visiting Schools in the country (2012). In Chile, Pedro Ignacio Alonso (AAPhD 2007) is Programme Director, AA Visiting School Santiago since 2009, and Franklin Lee (Columbia University, AA) does the same in Sao Paulo and Rio de Janeiro since 2011.

Group B was established by visits from an external academic circuit, with initiatives organized by architect researchers in order to develop workshops for short seasons, mainly in English. The organization is made by a local university or local students. The first experiments were carried out in Chile in order to use textual programming language at *Universidad de Chile*. (2006, 2007), which was an initiative promoted by Pablo C. Herrera and members of SiGraDi and the *Digital Design Fabrication Group* at MIT. The path was followed by *Universidad Peruana de Ciencias Aplicadas* (Lima, 2008) and *Universidad de los Andes* (Bogotá, 2009) including this time to Daniel Cardoso (MIT PhD) with the American Skylar Tibbits (present chair at the Self-

Assembly Lab, MIT). In 2009 there is a workshop with the French Marc Fornes (AADRL 2004) at the *Universidad Técnica Federico Santa María* (Valparaiso, 2009) under the organization of Marcela Godoy (UTFSM).

This group also includes the implementation under two types of monitoring: a) *Academic*: MIT *Fab Lab* (the first set installed in Lima in 2009) and, b) *Commercial*: *Rhino Fab Lab* (the first installed in Medellin in 2011).

The *Fab Lab* concept was prompted since 2001 by the *Center of Bits and Atoms* at the *Massachusetts Institute of Technology* (MIT CBA) by Neil Gershenfeld, as a program to democratize access to knowledge and digital fabrication tools. It arrives to Peru in 2009 (the same time as Ethiopia) the first systematized Latin American experience under the name *Fab Lab Lima*, the main case of this study. It was funded by the Spanish agency AECID and promoted by the IaaC. It begins with the selection of Benito Juarez and Victor Freundt as future managers and the investment for the purchase of equipment for *Universidad Nacional de Ingeniería* (Lima 2009-2011). Since 2012, this university has set up *Fab Lab UNI*, led by Peruvian Fab Academy graduates. Since 2013 other initiatives were opened as the *Fab Lab TECSUP*.

The MIT *Fab Labs*, seek to facilitate access to new tools for creation and production, using mainly *open source* technologies, seeking that the production of large analog machines belonging to traditional industries is transformed into low-cost personal products, so that, in the next few years, we could have our own factory at home to do (almost) anything (Gershenfeld, 2005, 19-27). Under this concept, different disciplines, cultures and age groups integrate, in research and development projects, ranging from rapid prototyping machines for biomedical, power generation with alternative systems, automation processes, complex architectural structures, and other technological solutions that catalyze the incubation of high-tech initiatives, focused on local issues with global impact.

On the other hand, *Rhino Fab Lab* use commercial software with open architecture created by *McNeel Associates*, the company that produces *Rhinoceros* and *Grasshopper.* They initially opened an online support group of sorts, for users of their applications that need help fabricating their designs. Currently, they enhance the implementation of methods used in the practice of architecture and design (being jewelry the most demanded), in order to explore possibilities to design and manufacture in different areas of the industry, giving access to jobs, forums, equipment for developers, and links to other experiences. Since 2009 they promote the *Design Optimization and Fabrication* (DOF), a workshop conducted in Colombia, Chile, Argentina, Peru and Brazil. These initiatives are promoted by the Colombian Andres Gonzales, who heads McNeel's Miami office with Jackie Nasser. The landmark case is the *Universidad Pontificia Bolivariana,* which since 2013 is the first to have graduates with a Minor in *Digital Fabrication*.

Group C, self-learning, is motivated primarily by postgraduate studies in the region and influenced by courses promoted by previous local implementations. In this group we find architects who not only seek a path for solving personal issues but they also replicate their experience in blogs, courses and tutorials, with the only motivation to spread their explorations. Chile is the country that presents the largest number of cases. Diego Pinochet, from the Master at UC and currently postgraduate student at MIT (2013), gets involved with programming under different written and graphic environments. He has co-led workshops at the *Universidad Diego Portales* and the *Pontificia Universidad Católica de Chile,* and since 2012 is in charge of the *Fab Lab* at the *Universidad Adolfo Ibañez*.

The Chilean Guillermo Parada (UNIACC, 2002), took part in the first workshop we did with MIT and *Universidad de Chile* (2006). After his Master's degree at UC under the guidance of Diego Pinochet, he establishes gt2p, a company dedicated to the industry of digital manufacturing applied to design and architecture. Outside Santiago, under the brand *Tectónicas Digitales*, Francisco Calvo and Katherine Cáceres (UNTFSM, 2003), established their first link with textual programming in the Marc Fornes' workshop (2009) and later that year they made the Spanish translation of Andy Payne's Grasshopper manual. Since 2010, they conduct fabrication workshops at *Universidad de las Américas* and other cities within Chile.

Current situation

Statistically, in 2012, the MIT *Fab Labs* reach more than 150 units, distributed in 23 countries worldwide. By 2014 it plans to open about 50 new *Fab Labs* in 13 new countries (Fab Lab MIT, 2013). Yet MIT *Fab Labs'* replication in the World has been more effective in developed countries (75% of all laboratories, 40% in Europe and 35% U.S.) than in those in the developing world (25%). By 2013, there are 14 *Rhino Fab Labs* worldwide distributed in 6 countries. Latin America represents nearly 20%, with one in Sao Paulo, in charge of Eliania Rosetti, and another at the *Universidad Pontificia Bolivariana*.

In the political arena the *National Fab Lab Network Act* of July 2010 was sponsored in the 111th U.S. Congress but was inactive until May 2013 when it was proposed again in the 113th Congress and again expects some response. It is expected that with this initiative, the equilibrium point in the U.S. will be about 500 *Fab Labs*.

Adverse circumstances to implementation: the *Fab Lab* Lima case study.

In the world there have been adverse implementation patterns: difficulties to manipulate three-dimensional shapes (Seely, 2004:28), high prices (Troxler and Wolf, 2010), or the establishment a place of installation. But in Latin America, what are the adverse circumstances? Are they just economic, or the sense of technological democratization that promote MIT *Fab Labs* in developed countries differs from the reality of Latin America? From the experience of Lima, factors have been identified, that limit Fabrication Laboratories' replication in the region:

Economic Factor. The acquisition of tools and digital fabrication equipment in Latin America can be between 3 to 8 times more expensive than in Europe or the U.S. (import expenses, transportation, customs, cost of living, etc.). To this is added the prior cost of staff training for the direction of the Fabrication Laboratory.

Management and Maintenance. Just as with the implementation of the computer, a Fabrication Laboratory is not a matter of just having some machines. San Martin (1995, 48) argued that *"it is not a logical consequence that just because classrooms have advanced audiovisual and computer equipment, or host a satellite dish on their roof, is the school open to the world, more cutting edge or deemed more modernized."* A Fabrication Laboratory is a space with machines such as an ink plotter, maintenance and a permanent staff is required, to give short-term solution to these needs, and this requires expertise and training. To access *Fab Academy,* which provides instruction and supervises investigation of mechanisms, applications and implications for digital fabrication since 2008, is on average 6.5 times more expensive in Latin America and even up to 40 times in some African countries. The 2012 *Fab Academy* version had more than 80 participants registered worldwide: 55% in Europe and 20% of the U.S. The *Fab Academy* provides the training required to belong to the network, has a duration of six months beginning in the first month of each year, taking about 80 hours per week.

Fig. 1. How many months should a person save from their salary in order to pay the inscription cost to *Fab Academy*?
Source: http://fab.cba.mit.edu/about/labs/ Per Capita 2011, IMF.

Administrative Factor. The bureaucracy is still another problem on creating and implementing a Digital Fabrication Laboratory, especially those promoted by public entities. Even with funding, the implementation of *Fab Lab* Lima took nine months, which is three times more than in the U.S. or Europe. An even more extreme case is *Fab Lab* Addis Ababa in Ethiopia, which under similar conditions to that of Lima, took 24 months to complete its installation.

Educational Factor. The implementation in Europe and U.S. occurs in spaces that encourage design issues on the instrumentalization of a process. In Latin America the implementation of technologies still exists as an extension or continuation of the practice of drawing and, not being integrated into the design, aims education to technological consumption, but not development or discovery. As a result, most professionals, companies or government organizations centralize their activities only in production/trade and very rarely in innovation. Less than 2% of the Economically Active Population of Peru incorporates innovation and development activities. At the low level of innovation, an entrenched culture of misguided competition sums up: "I win, you lose." Most public and private institutions speak of cooperation, but hardly encourage it.

Conclusions: Reflections that promote opportunities

Incentive programs and scholarships in developed countries
Countries that are implementing *Fab Labs* in the region, have invested during the past decade in scholarships programs that give the group of teachers and doctors who have returned to their countries, stable and self-sufficient. Among them are Chile and Brazil, and then Colombia and Argentina. Unlike Peru, Bolivia, Ecuador and Uruguay, where, even though there are some self-management initiatives, these have been funded by the students themselves, who returned to their countries for the current economic instability in developed countries.

They are thus the self-managed and sustainable initiatives. There is another group of institutions that do not have a clear organization and operation of a *Fab Lab*. It is divided by two types of supervision (academic and commercial). This supervision is considered by the academic world because the alliance minimizes implementation risks in the short and long term, others do it aiming for commercial differentiation, considering that the number of schools of architecture in Brazil is over a hundred, and in Chile and Peru are almost fifty, mainly concentrated in the capital cities. This does not take into account that both supervision types produce significant results in controlled contexts, because they reflect global experience that minimizes implementation risks. Elster (1983) argued that *"the technological evolution differs from the biological because the changes are far from being totally random, but are directed to a certain extent."* And if some of these experiences have been successful, we cannot take one or more of them as a generalization if we do not compare them to each other, because just as with the implementation of the computer, this is not a matter of just having some machines.

The Fabrication Laboratories in the region must assume a dynamic role in the economy and social development, becoming integrating agents and taking into account local potential. In that sense, the Latin American context offers some opportunities that we have identified:

Multiculturalism. By analyzing the experiences produced by the Digital Fabrication Laboratories, it appears that fabrication in Latin America aims for a minority, and prioritizes object over user. It is a system produced with universal models from industrialized context that, from the theory, allow us to experiment in part of our cities. We have to consider, however, that in many regions of Latin America, the bulk of architecture occurs in the other, marginalized, 70% of the population. This happens especially in populations with ancient based traditions, based in native technologies that end up adapting to urban contexts. Latin America inherits a wide range of craft production processes in various fields, such as carving, textiles, and jewelry, whose encounter with digital manufacturing can generate innovative responses, moreover, considering that 80% of the labor force is engaged in handicrafts and semi-industrial production. Digital fabrication can optimize the mechanical processes and provide more time to the artisan/producer to invest in creative processes directly affecting the value of the product and improving their quality of life.

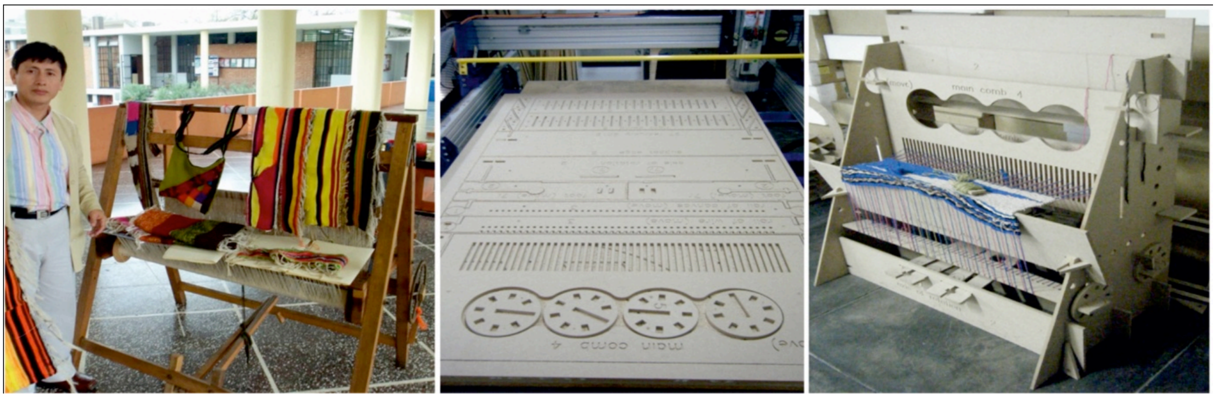

Fig.2. Project Digital Loom, optimizes in 60% the loom's production time, to a similar cost as that of the traditional process. Source: Fab Academy Lima-2012.

Eco-Diversity. The Andean region is considered the most rich in biodiversity per km2 of the planet, if we add the natural variety and water resources of the Amazon region, we get a privileged territory for the development of new technologies in line with the demands of our time. Digital manufacturing can draw on the assortment of materials, exploration of complex shapes, bio-regenerative manufacturing processes, etc., and simultaneously meet the demands of energy, health, education, etc., of one of the areas that, paradoxically, has the world's largest social poverty.

Fig. 3. Project ECO-FAB, laboratory for the integration of digital fabrication and not-industrialized materials: Bambu, reeds, mud, etc. Diego Machuca, Fab Academy Lima-2012

Social Capital

Self-learning is not an everyday a cultural practice. Because education in the region is highly dependent on repetition and imitation, participants generally do not have clear goals or problems to focus their efforts or to take technology as an ally of its processes. Graduate studies are part time and are performed after an 8 hours work day, resulting that the average student works 40 hours a week and studies 4 to 8 hours.

Despite the many economic, bureaucratic and educational constraints, or perhaps because of them, in Latin America continually emerge groups of young visionaries facing social problems such as insecurity, access to housing, lack of public spaces, etc. Through various creative proposals they have caught the attention of Europe and the U.S., through special issues on Latin America such as *2G Dossier* (2008), *Harvard Design Magazine* (No. 34, 2011), *Architectural Design* (No. 211, 2011) or *Lotus* (No. 143, 2010). These groups constitute a significant hidden force, through which alternative methods for channeling the benefits of digital fabrication to citizens could be developed. Entrepreneurship in our region has also been evident in the last *Fab Academy* (2012), where Lima had the largest number of graduates globally. But more important than the number of graduates is certainly the spirit of social and technological convergence that occurs in them: a growing culture of innovation with inclusion.

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