Innovation and Education: lessons learned from Cuban Science, Technology and Innovation System

Armando Rodríguez Batista
armando@citma.cu
Vice Minister, Ministry of Science, Technology and Environment of Cuba

ABSTRACT

The beginning of Science and Technology-Based Innovation (STI) policies in Cuba should be traced to 1961, with the so-called Literacy Campaign that declared the Nation as the First Latin-American Country Free from Illiteracy. From this moment to our days, Cuba has developed a significant Research and Development (R&D) infrastructure and committed human resources on Science, Technology and Innovation.

This paper explores the links among Cuban Science, Technology and Innovation System and National Education System for the achievement of scientific technical achievements, within the context of the *actualization* of Cuban Model for Economic and Social Development. Also, It takes into consideration the role of education and training within a learning economy and Mode 1 to Mode 2 knowledge production process transition. A comprehensive approach to national, sectorial and local innovation systems actors and interactions with education and training experiences is discussed, as well as general reflections regarding Innovation and Education within the National Economic and Social 2030 Plan, which may contribute to a better understanding of the role of education within the Cuban National System of Technology and Innovation.

KEYWORDS: Innovation System, Science and Technology-Based Innovation, Cuba

Innovación y Educación: lecciones aprendidas del Sistema Cubano de Ciencia, Tecnología e Innovación

Armando Rodríguez Batista
armando@citma.cu
Viceministro, Ministerio de Ciencia, Tecnología y Medioambiente de Cuba

RESUMEN

El inicio de las políticas de Innovación Basada en Ciencia e Tecnología (CTI) en Cuba debe remontarse a 1961, con la denominada Campaña de Alfabetización que declaró a la Nación como el Primer País Latinoamericano Libre de Analfabetismo. Desde ese momento hasta nuestros días, Cuba ha desarrollado una importante infraestructura de Investigación y Desarrollo (I+D) y recursos humanos comprometidos en Ciencia, Tecnología e Innovación.

Este artículo explora los vínculos entre el Sistema Cubano de Ciencia, Tecnología e Innovación y el Sistema Nacional de Educación para el logro de resultados científico-técnicos, en el contexto de la actualización del Modelo Cubano de Desarrollo Económico y Social. También toma en consideración el papel de la educación y la formación dentro de una economía del aprendizaje y la transición del proceso de producción de conocimiento del Modo 1 al Modo 2. Se discute un abordaje integral de los actores de los sistemas de innovación nacionales, sectoriales y locales y las interacciones con las experiencias de educación y formación, así como reflexiones generales sobre Innovación y Educación dentro del Plan Nacional Económico y Social 2030, que pueden contribuir a una mejor comprensión del rol de la educación dentro del Sistema Nacional de CTI de Cuba.

PALABRAS CLAVE: Sistema de innovación, innovación basada en la ciencia y la tecnología, Cuba

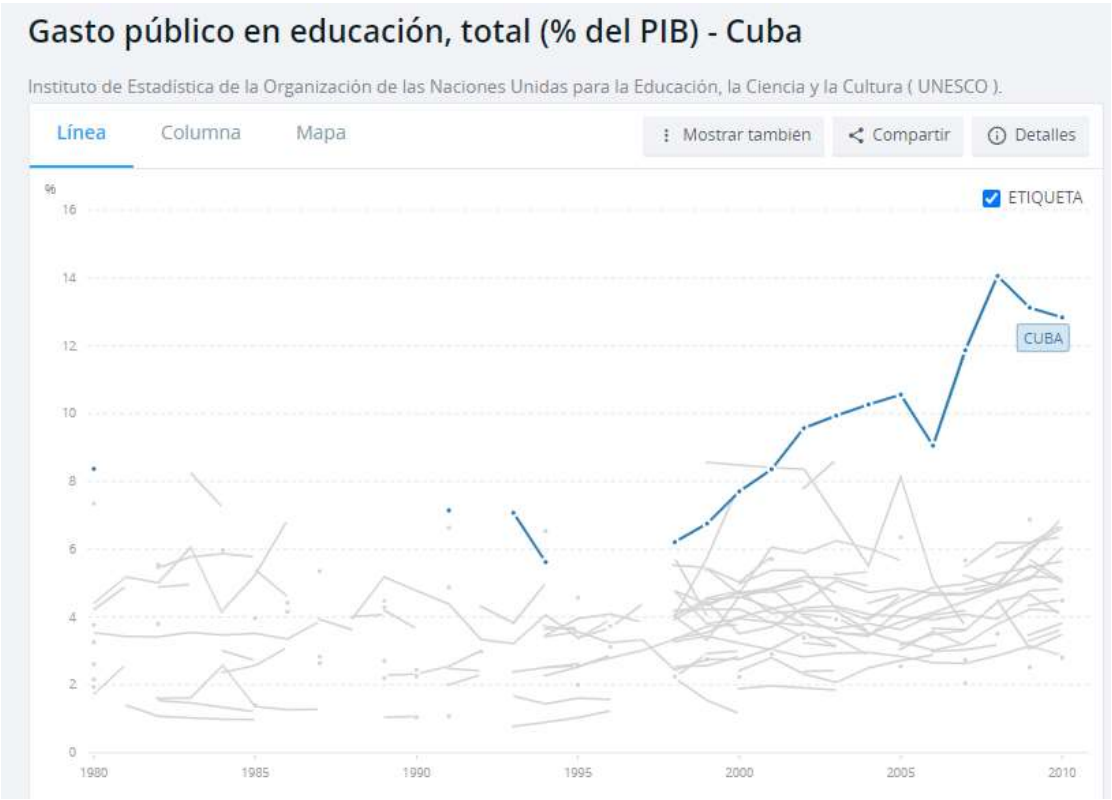
Introduction

The starting point of Science and Technology-Based Innovation (STI) policies in Cuba, also an inclusive innovation policy, should be traced to 1961 Literacy Campaign that declared Cuba as the First Latin-American Country Free from Illiteracy. Before that time and according to the population, electoral and housing census (1953), 23 percent of the population was illiterate. This achievement is not considered only an educational policy but also a social innovation policy because it significantly contributed to the increase in well-being and competitiveness of both society and the country.

According to Stiglitz "Social innovation is new responses to pressing social demands, which affect the process of social interactions. It is aimed at improving human wellbeing" (Stiglitz cited in Hubert et.al., 2010 p.33). The process was composed of several elements (Guide to Social Innovation, 2013) : (i) Identification of new/unmet/inadequately met social needs (High levels of illiteracy), development of new solutions in response to these social needs (Literacy Campaign – 1961), evaluation of the effectiveness of new solutions in meeting social needs; (December 22, 1961 the island was declared a Territory Free of Illiteracy), Scaling up of effective social innovations (Cuban Literacy Program -*Yo Si Puedo*- Yes, I Can)

Ever since, Cuba has developed a significant Research and Development (R+D) infrastructure and dedicated human resources, based on a strong National Education System, as recognized by UNESCO, not only because of the quality of education, but also for a very high level of gender equity and access, and with the support of Cuban government (12- 13% of Central Government budget in period 2011-2016).

Figure 1: Latam comparison about public spending on education



Fuente: Banco Mundial https://datos.bancomundial.org/indicator/SE.XPD.TOTL.GD.ZS?contextual=region&locations=CU

National Innovation System concept is implemented in Cuba since 1995 and Sectorial and Local Innovation Systems have been fostered. Interaction among education and innovation has been promoted all over the country, with an outstanding role for STI Institutions and Universities. Important cooperation achievements with education have been made on sectorial innovation systems, such as Sports, Physical Education and Recreation, Medical Biotechnology and Environmental/National Disaster Management, as well as on Local Innovation Systems at the municipalities.

On the other hand, Cuban R+D institutions, universities and enterprises have developed various interaction experiences; according to the country own characteristics. A recently STI Institutions reorganization policy encouraged research centers and universities interaction with productive and value chains. This policy should be considered as part of the national framework adaptation to the learning economy.

National Economic and Social 2030 Plan declares "Human Potential, Science, Technology and Innovation" as strategic for the development of the country, standing out the role of Education within National STI System. A new National Policy for Reorganization of Cuban National STI System is under analysis, focusing on two main challenges: Increasing social and economic impact of STI and Preserving and developing Cuban national STI human resources (PCC, 2016).

In this context, reflections regarding connections among innovation and education may contribute to a better understanding of the role of education within Cuban National STI System. Besides, it may suggest directions for future studies of the role of education within the theory of Innovation Systems.

The theory of Innovation Systems and the role of Education

The Innovation Systems (IS) Theory was conformed as a result of Freeman (1987) and Lundvall (1985) works. Freeman described the systemic characteristics of innovation process in Japan, while Lundvall analyzed the role of learning processes within Denmark and Scandinavian countries. After these significant remarks, substantial contributions have been made, focusing on IS methodology conceptualization as well as describing empiric approaches to national, sectorial and local scenarios, that revealed the importance of the idea to fulfill the needs of understanding knowledge production process and, through that, adjusting STI policies to real context of the countries. Cassiolato et al. (2009), Dutrénit and Sutz (2013), Liu and Lundin (2009), Atkinson (2014), Arocena and Sutz (2003). Regarding the local and municipal level, it is quite important the concept of Local Innovation and Production Systems (LIPS), developed in Brazil. Lastres and Cassiolato (2007)

According to Lundvall (2015: 3): *"The national innovation system is an open, evolving and complex system that encompasses institutions and economic structures. The quality of its elements and of the relationships between elements determines the rate and direction of innovation."*

Innovation Systems definitions may differ, regarding systems' narrow or wider sense. Núñez (2014) Narrow sense reduces IS to R+D activities and associated infrastructures. R+D institutions play the most important role within the IS. Is based on "science push" approach and focused on radical innovation Nelson (1993), while wider sense emphasizes in the acquisition and use of knowledge and on production and innovation learning process. It recognizes the role of R+D, but also a diversity of actors and activities that promote the production, use and diffusion of knowledge, both tacit and scientific, calling for attention to Know Why, but also Know What, Know-how, Know Who, etc. Lundvall and Johnson (1994)

In any of these approaches, the importance of universities and education is acknowledged. Education, from elementary school to technical, undergraduate and postgraduate, is considered as part of science and technology sub-system within the NIS. Nevertheless, the wider proposal brings a more comprehensive explanation to the changes on knowledge production process, described by Gibbons M. et al. (1994) as the knowledge production transition: from Mode 1 to Mode 2.

The idea of IS comes to reflect actors and interactions that participate in the innovation process on developed countries, which economic, social and cultural scenario widely differs from developing nations. Nevertheless, national educational systems seem to be relevant in every context Cassiolato et al. (2009), even in those with less developed educational and scientific communities. In these cases, the use of IS theory and linking it with the national education system, may provide inputs for appropriate policy making.

Fortunately, the role of education only slightly varies from national, regional or local level, in countries with high education standards like Cuba, as acknowledge by UNESCO (2015), with no significant differences from urban to rural areas access to education. Otherwise, this would result in a weak input for education to IS, particularly in the learning economy scenario, where knowledge became the most important resource and also the late hope to succeed with problems such as global warming and poverty (Lundvall, 2015)

During last decades, public policies have been adjusted, particularly redefining the role of the state, consequently reducing public budget for education and STI, which negatively affects educational and science institutions that must struggle for funding from the private sector or even apply for competition funds (UNESCO, 2002). In this particular scenario, new organizational forms are required at the universities to respond to the new challenges of the learning economy (Lundvall, 2002). Even if several developing countries have promoted STI policies to foster innovation, the lack of human resources which is strongly connected to education, considerably reduce national capacities to reach innovation objectives (Arocena and Sutz, 2009).

How to measure innovation and how it helps (or not) its links with education

As already mentioned, many countries have designed STI policies to support national economic and social goals. These actions have been followed by the development of indicators to evaluate policy evolution, as patents, innovation surveys and papers, but the dynamics of the interactions are still difficult to be described (UNCTAD, 2010)

Most evaluations are based on linear innovation model Bush (1945) that considers input indicators, such as, investment, infrastructure and human stocks to find out the state of STI. The limitation of these ideas has been appointed by López and Luján (2000: 2): "*In order to serve society, science must forget society*". These approaches may not reflect adequately the impact of a complex sector like education on innovation. However, many organizations have proposed indicators to evaluate learning capacities and enterprises-universities interactions (OECD, 1996)

New challenges demand from public policies and indicators the inclusion of new topics, emerged from different sectors of society. This is crucial to achieve national goals in a learning economy, in which education is critical. Challenges are even more complex if the objective is to fulfill the construction of sustainable societies (UN, 2015)

Trends in the research of NIS are described by Balzat and Hanusch (2004). Nevertheless, complexity of the topics will demand a constant identification of indicators to characterize actors and interactions, with relevant aspects still to be developed, such as: *"Implications of the NSI-approach for economic theory, NSI and economic development, NSI welfare states and inequality, Environmental sustainability of national innovation systems, Innovation in the public sector"* (Lundvall, 2010: 43).

Cuba: the concept of inclusive innovation started with education.

Although the concept of Inclusive Innovation is relatively recent (OECD, 2013), the idea of social inclusion, equity and equality has been deeply considered by the government of Cuba since the triumph of the Revolution, and consequently assumed as a policy of the State (Rodríguez, 2016)

As already mentioned, Literacy Campaign, which declared Cuba as the First Latin-American Country Free from Illiteracy, marked a starting point for STI and inclusive innovation policy in the country.[1] Until then, the Nation had one million illiterates, no research centers and no R+D programs and only 3 Universities. It is very difficult to conceive a NIS if people don't have access to education. A recent report for the Economic Commission for Latin America and the Caribbean focused on the inefficiency and unproductivity of inequality and identified social and economic costs of inequality (ECLAC, 2018).

The OECD (2015) discusses the importance of scaling up inclusive innovation, through the development of innovation policies for inclusive development. However, in the case of Cuba, the population has access to free universal education, health services and social security; as a result of this approach, inclusive innovation products and services embraces the whole society; as a result of a strong public welfare policy. Within this context, education is crucial to achieve inclusive and sustainable society goals.

Overview of Cuban National STI System

The acknowledgement of Cuban National Science, Technology and Innovation System (NSTIS) took place in 1995, defined as "the organization form that allows the participative application of the national science and technology policy, established by

Cuban State and institutions for a period of time, taking into consideration national strategy for social and economic develop and national strategy for science and technology, which are strongly related". CITMA (2001) NSTIS reaches the whole society; consequently, knowledge and creative initiatives are focused on the solution of the main problems of the Nation, but also respond to sectorial, regional and local needs.

STI planning is organized according to main priorities approved by the government, which are strongly related to the needs of Cuban population: Biotechnology & Healthcare, Food Production, Renewable Energy and Energy Efficiency, Information and Communication Technologies, Climate Change and Sustainable Development, Water Management, Comprehensive Development of the Population, Basic Sciences and Nanotechnology [2] (CITMA, 2018).

Cuba has developed a significant R+D infrastructure and committed human resources. According to Cuban leader Dr. Fidel Castro Ruz (1960): "… The future of our Nation will necessary be a future of people of science, a future of people of thoughts …"

At the beginning of 2018, Cuba had 214 STI Institutions, 135 of which are R+D Centers and 63% functioned as STI Enterprises. In addition, the number of Universities reached 50 and embraced 30 STI Centers within the university campus and 94 municipal campuses. STI institutions' agendas include: Agriculture and Livestock Sciences (26%), Life Sciences (45%), Natural and Basic Sciences (54%), Engineering and Technical Sciences (46%), Defense and Security (27%), Social Sciences and Humanities (34%) (DCTI-CITMA, 2018)

Cuban 2016 Budget for STI reached 0.91% of national GDP, with a crucial role for State funding allocation. Nevertheless, enterprises were responsible for 35% of STI funding, which is a significant number if comparing with Latin-American countries (Chia and Rodríguez, 2017; RICYT, 2017).

A recently STI Institutions reorganization policy encouraged R+D centers and universities interaction with productive and value chains, either functionally or structurally, according to existing conditions and foresight studies. The quality of these connections is critical and frequently not associated only to research, but to general or specific regulations on economic, financial and administrative issues. This policy should be considered as part of national framework adaptation to knowledge production changes within the learning economy (Consejo de Estado, 2014).

Cuban National Education System contribution to National STI System

From the perspective of NSTIS, National Education System is comprehended as part of the *Education and Training Environment*, which also includes ministries, enterprises and institution's training facilities. They carry out formation and training of human resources devoted to planning, organizing and manage STI institutions and activities (CITMA, 2001)

Cuban indicators on STI Human Resources are not typical for a small developing country and are located all over the country. This achievement is strongly connected to the promotion of a strong universal Education System that allows widespread distribution of

STI institutions in Cuban provinces, with a mayor portion for Havana (54%) and roughly 10% located in rural areas (DCTI-CITMA, 2018)

The development of education is sustained in mayor funding efforts by Cuban government. Figures are particularly relevant if analyzing Central Government budget for Education (among 12-13% in period 2011-2016). The share increases for Local Governments as high as 20-33% (ONEI, 2017)

As a result, by 2016, Cuba had 86 426 personnel engaged in STI activities, (53% women) and 57 198 R&D Personnel in STI Institutions (54% women). Up to 77 % had higher or technical degrees and 6 839 were categorized as researchers (48% women). This data not only confirms the achievements of National Education System on professional's formation, but also a very high level of gender equity. Cuban relative indicators are as follows: 600 Researchers and 1300 PhD per million inhabitants; 16 513 R&D personnel per million total employees; 1 165 000 college graduates (ONEI, 2017; CITMA, 2018)

Every year, Cuba's human resources formation includes approximately 300 new senior researchers and 150 new senior technologists. More than 900 new PhD themes get approval, with mayor contributions for universities (49%) and Health System (29%). Main topic for PhD is Education (38%), with lesser contribution for Medical Sciences (15%), Social Sciences (12%) and Technical Sciences (12%) (CITMA, 2018).

Initial enrollment in higher education in every branch of science shows a rate of more than 200 000 students in period 2011-2016 (60% woman). Larger contributions (course 2016-2017) comes from Medical Sciences (35%), Pedagogical (21%), Technical Sciences (14%), Social Sciences and Humanities (10%), Economical Sciences (8%), Physical Culture (5%), Agricultural Sciences (4%), Natural Sciences and Mathematics (2%) and Art (1%). Higher education graduates amount, in 2011-2016 period, may vary from branch of science but, as a rate, reaches 60 000 per year. Similar figures can be appreciated by evaluating technical and professional education initial enrollment, roughly 200 000 students, 64% of each as medium level graduates and 36% as skilled workers (2016-2017 course)[3] (ONEI, 2017).

Besides, it is important to mention the role of universities in the education of leaders on the subject of innovation. Within 2011-2018, about 1500 national level leaders (Cuban Communist Party, government and public enterprises) have been granted education on Public Management, which includes innovation as a topic. These courses have been developed by National School for Party and State Leaders, in the University of Havana. The number is far huge, 21 000, if considering nationwide courses provided by 17 universities and ministries schools (Delgado, 2018).

Cuban National Education System plays an essential role within NSTIS, not only providing highly educated labor force, but encouraging professors to participate in R+D projects and fostering innovation to provide students a better educational experience. In 2018, the Ministry of Education financed 253 R+D+i projects in Pedagogical Sciences, 91 associated to the National Program "Current problems of the Cuban Education System. Perspectives and Development" (Escalona, 2018).

Nevertheless, if we keep faithful to the importance of culture, confidence and historical factors within the NSTIS, it is quite relevant to note that Cuban National Education

System also cultivates moral values, focusing on a comprehensive, humanist and citizenship education, for a peaceful and harmonious coexistence (Velazquez, 2017)

Crosscutting experiences to foster education, continuous learning and innovation

By recognizing the importance of interactions among NSTIS's actors, Cuban government has created organizations to promote training, continuous learning and innovation (CITMA, 2018):

- 15 Science-Production Poles at regional level, fostering regional and local priorities and 3 national Science-Production Poles (coordination mechanisms among IS actors, led by government and including Social Sciences).
- Special Groups of experts of Universities and Agriculture STI institutions (advising farmers, public enterprises and cooperatives).
- Cuban Academy of Sciences (promoting STI debates and social recognition).
- Young Technicians Organization (encouraging continuous learning among people less than 35 years old and sponsoring Awards for young researchers).
- Forum for Science and Technology (gathering all society to stimulate creativity on the solution of daily life problems of institutions and communities).
- National Innovators Association. Founded under the influence of *Ché* Guevara's ideas as Minister of Industry: "Worker: build your own machinery", as a response to USA's unfair blockade against Cuba, that has endured for more than 55 years.

Education, Innovation and Local Development

Universities and STI institutions have played a relevant role in advising Municipal Governments to include innovation within local strategies for economic and social development. Two different approaches have been developed: one experience is related to Local and Community Development Center (CEDEL) that created a "Methodological guide for design and management of the Municipal Strategy for Local development", based on projects experiences in more than 60 municipalities. These strategies were approved by Municipal Assemblies and identified priorities for local development, considering regional and local human and natural resources and population interests. A very important aspect is the participation of the people in the elaboration of the strategy that includes general assemblies in the communities. Universities and local schools provided experts for strategy elaboration and assumed leaders education on local development (Guzón, 2018).

Another important approach has been developed by University Knowledge and Innovation Management for Local Development Network (GUCID) which introduced the concept of Local Innovation and Production Systems (LIPS) in Cuba (Núñez and Alcázar, 2016). Main GUCID achievements have been the identification of LIPS actors at the municipality, the construction of local networks and the study of knowledge absorption

capacities of local actors. A quite important objective is also education in innovation and innovation projects formulation. Based on GUCID experiences, Núñez and Montalvo (2015) identified Cuban higher education actors involved in local development: universities, STI institutions and municipal university councils.

Within the context of a centralized economic planning, these two experiences have provided valuable inputs for policy implementation. As a result, the Ministry of Economy and Planning has encouraged Municipal Governments to dedicate 1% of Local Governments Income to Local Development Projects. Likewise, almost every actor agrees that local development is not a spontaneous process, so implication of universities and research centers remain crucial (Guzón, 2018).

Education and Sectorial Innovation Systems

Cuban national and ministerial policies recognize and promote sectorial innovation systems (SIS) which may include areas such as: Agriculture; Energy; Sugarcane; Environmental/National Disaster Management; Sports, Physical Education and Recreation; Higher Education; Nuclear and Advanced Technology; ICT; Medical Biotechnology. CITMA (2001, 2018)

General objectives of SIS have been the identification of IS actors and promoting articulation, capacity building and common research agendas related to sectorial but also to national and local priorities. Efforts have been made to avoid SIS limitations, such as, reproducing internal structure of ministries and lack of linkage among actors. National polices have encouraged interaction among SIS and education, resulting in fruitful linkages. We will mention 3 examples:

A strong and sustainable connection with education has distinguished the Sports, Physical Education and Recreation SIS, maybe not a common one, but very robust in Cuba, where sports and recreation are considered people's right. This SIS has been supported by national wide sports education system, including provincial universities, as well as research institutions. Main targets are not only high performance athletes with international level results, but common people recreation and Physical Education (Ilizástigui, 2018)

Likewise, Environmental/National Disaster Management SIS has developed relevant links with education, introducing environmental, climate change and natural disasters prevention topics in curricular formation of students. Innovation in services has been carried out both by universities and research centers, with participation of local communities and government officials. The setting up of these crucial services for population and economy have strengthened connections among academia and National Security Institutions and increased social recognition of STI, also encouraging younger generations to study environment related sciences like Meteorology.[4] Social recognition of scientist and professors plays an essential role when facing climate changes adaptation tasks that include actions which may affect local people and communities, such as small village's relocations. Society confidence on education and scientific community may increase the probability for successful implementation of National State Plan for Climate Change (Stone, 2018).

Medical Biotechnology SIS is also a quite valuable example of education-innovation interaction, since the creation of the Biological Task in 1981, which focused on the development of biotechnology and pharmaceutical industry in Cuba. Simeón (1997) From this experience, it was later created the Biotechnology Pole, that gathered recently founded R+D centers on genetic engineering, molecular immunology, human vaccines, laboratory animals production, neurosciences, micro analytical techniques, etc. with more experienced institutions established during first decades of the Revolution. Núñez et al. (2011) Most of the human resources that initiated this enormous Project and also the skills of the engineers and scholars that have developed national technologies or adapted international ones, were educated and trained by Cuban National Educational System, with a mayor role for Medical Universities and Hospitals.

Curiously, during the creation of biotechnology institutions, important decisions related to human resources management were approved, such as the implementation of the Scientific Reserve concept in 1991, as a position for young personnel to be trained as a researcher. This practice was extended in 1998 to universities and science institutions all over the country (CITMA-MTSS, 1998)

The role of universities within the National STI System

Universities in Cuba are crucial for NSTIS and have a vocation for research and innovation to achieve society goals. Provinces' distribution of universities allows its intervention both at national and local scenarios, by playing a remarkable role on the solutions of government and communities problems that constitute inputs for the formulation of researchers' agenda.

Núñez and Montalvo (2015) acknowledge that Cuban universities within NIS focuse on ensuring college graduates and postgraduate training, developing research activities, advising for public policies, implementing leaders and executives training and contributing to support local development strategies.

Although systematic formation of people with the capacity to promote innovation is recognized as a mayor task, the implication of universities research groups to the solution of concrete problems of industry has become a new mission on knowledge production process Mode 2. Nevertheless, the experience of "*university originated industries*" remind us the importance of basic research, not necessary linked to short term needs of industry and society (Arocena and Sutz, 2003).

Following this idea, and considering the political will of Cuban government, universities have played a relevant role on the development of inclusive innovative products, like Haemophilus influenzae Type b Vaccine*,* one of the Cuban scientist's papers on *Science Magazine –(*Verez-Bencomo et al 2004)-*,* or services for National Security like monitoring and early warning for health and natural hazardous events (like hurricanes) or diseases (such as dengue, chikungunya, zika).

On the other hand, as an example of short term response to economic demands, Cuban Informatics Science University (UCI) developed "GINA: a comprehensive Management System for Cuban Customs"*,* that was acknowledged with the Technological Innovation National Award 2017 (CITMA, 2018)

Additionally, Cuban universities and enterprises have developed a diverse set of interaction experiences, such as: joint research facilities among universities and biotechnological enterprises, agriculture extension programs, technology transference offices at university campus, student's vocational training programs on enterprises, project incubators of startups, joint research projects and Technology Park on ICT. Meanwhile, a national policy to foster linkages among academia and enterprises is under preparation (Lage, 2012; Hidalgo, 2018; CITMA, 2018)

Despite of Cuban government efforts, promoting innovation at universities faces a new scenario resulted from transformations in knowledge production process during recent decades. The learning economy brings huge challenges for societies and consequently Lundvall (1996) suggests that a new deal is necessary to be achieved, where access to education and learning is a critical factor.

According to Alarcón (2016: 8) former Cuban Minister oh Higher Education: "…*the idea of Innovative University emphasizes the need of creating institutions that will be capable of permanent transformation, ready to take on the huge challenges of our time and our societies… by improving own management models*…"

Nevertheless, important aspects related to university management within the learning economy are being discussed, like the role of intellectual property rights and technology transference, the construction of production facilities within the campus, as well as marketing associated teams. Consequently, Cuban universities response to Mode 2 knowledge production transition is still under construction.

The challenges ahead

Cuban National Economic and Social Development 2030 Plan, declared "Human Potential, Science, Technology and Innovation" as a strategic axis. PCC (2016: 22) This decision is strongly related to Cuban Communist Party's (PCC) VI Congress Guidelines for social and economic development mandate to impulse research and technological innovation both in STI institutions and universities. PCC (2011)

Important 2030 Plan objectives linked to education and innovation are: "*To strengthen integration and rationality of the NSTIS, as well as the development of human resources and infrastructure and to develop highly qualified human resources and assuring appropriate conditions and stability*". PCC (2016: 22) This Plan is referred to UN Sustainable Development Goals for 2030, in which education is crucial (UN, 2015).

Within this scenario, a new Policy for Reorganization of Cuban NSTIS is under analysis. Policy proposal was elaborated with contributions from Cuban Academy of Sciences, regarding challenges and opportunities on topics like funding access, human resources, infrastructure, papers, patents and international cooperation (ACC, 2013; CITMA, 2018).

As declared by the Ministry of Science, Technology and Environment -national coordinator of NSTIS- main challenges are: Increasing social and economic impact of STI and Preserving and developing Cuban national STI human resources. As already discussed, this goals can only be achieved, by continue strengthen national, sectorial, regional and local IS with education (CITMA, 2018).

These challenges were appreciated by Lundvall (2015: 9-10): "*Perhaps the most important challenge for Cuba in the coming decade will be to give a practical response to the question: how to build a stronger national innovation system with Cuban characteristics while at the same time entering more and more into processes of global exchange of knowledge, technologies, capital and commodities… This will require an unprejudiced and pragmatic analysis of the strength and weaknesses of Cuba's national innovation system as well as an analysis of strategic threats and opportunities…"*

It would also be an important contribution to actual discussions on the impact of learning economy on education, innovation and social and economic development in developing countries, in the Centenary of Cordoba's University Reform of 1918.

Concluding remarks:

National Innovation System concept is implemented in Cuba since 1995, with a crucial role for education (coming from 1961 Literacy Campaign). National Education System is comprehended as part of the *Education and Training Environment*, which also includes ministries, enterprises and institutions training facilities.

Education participation on Central Government budget performance is quite important (12-13% in period 2011-2016). Cuban National Education System achievements on professional's formation and equity are recognized by UNESCO.

Interaction among education and innovation has been promoted all over the country, with an outstanding role for STI Institutions and Universities. Important cooperation achievements with education have been made on sectorial innovation systems, such as Sports, Physical Education and Recreation, Medical Biotechnology and Environmental/National Disaster Management, as well as on Local Innovation Systems at the municipalities. Crosscutting organizations have been created to foster integration and innovation has been included as a topic on leader's education.

R+D institutions, universities and enterprises have developed various interaction experiences. A recently STI Institutions reorganization policy encouraged research centers and universities interaction with productive and value chains. This policy should be considered as part of national framework adaptation to the learning economy.

National Economic and Social 2030 Plan declares "Human Potential, Science, Technology and Innovation" as Strategic for the development of the country, standing out the role of Education within National Science, Technology and Innovation System. A new National Policy for Reorganization of Cuban National Science, Technology and Innovation System is under analysis and will focus on two main challenges: Increasing social and economic impact of STI and Preserving and developing Cuban national STI human resources. As already discussed, this goals can only be achieved, by continue strengthen national, sectorial, regional and local innovation systems with education. Finally, we have presented multiple directions for understanding the role of education within Cuban NSTIS, as a first step for future indicators proposal.

Notes:

1. Cuban Teachers developed 2006 UNESCO King Sejong Literacy Prize, method Yo si puedo (Yes I can), to teach reading and writing to illiterate people on their own language (Quechua, Aymara, Creole and Swahili…), at a very low cost and in a short period of time (1 person in 7 weeks, using 1/3 of estimated budget). This inclusive innovation service has carried out literacy and culture to more than 3.5 million persons in 20 countries (Angola, Namibia, Haiti, Venezuela, Bolivia, Nicaragua…).
2. Government approved the foundations of Cuban S&T policy: development of own human resources; fostering Cuban social and economic development; assimilation of international technologies and knowledge; development of indigenous technologies and integration.
3. Recently efforts to increase the number of Natural Sciences and Mathematics graduates have been made, by incorporating students in university facilities during their last bachelor course. It provides more appropriate conditions for identification and follows up undergraduates' needs and skills and fostering vocational training.
4. Notorious professor and meteorologist José Rubiera became a national hero since his last decade's works as Forecast Department Chief, almost considered as "*an antidote against hurricanes"*.

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