TECHNOLOGY OF MANAGEMENT FOR SCIENCE AND INNOVATION IN THE UNIVERSITIES

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Abstract

The work had as study object the management of science and innovation in the universities, important process to satisfy the technological demands of society; however, it presents theoretical, methodological and practical limitations that it implies their improvement, because systemic, flexible, participative and proactive technologies for their management don't exist, that which causes that these institutions obtain insufficient results in the indicators of this process. The objective of investigation was to propose a technology of management systemic, flexible, participative and proactive for science and innovation in the universities, and in him was made a study with marked critical character of state of art of this phenomenon in the world, it which constitutes an instrument of invaluable value for the historical, logical and prospective studies related with this thematic. The main existent theoretical methods were used, as well as other methods, technical and instruments for the gathering, prosecution, analysis and interpretation of data and a study of unique case was developed. The main results were the conceptualization of management of science and innovation in a university, the foundation of their theoretical and methodological platform (theoretical model) and a technology for their management; same that constitutes a theoretical-practical contribution to the conception process and organization of management of this process in the universities and an important methodological and organizational instrument. The application of technology in a cuban university corroborated its effectiveness through the significant improvement of the results in the evaluated indicators.

Keywords: Management, technology of management, science, innovation, university.

1. INTRODUCTION

The university is a very important social institution for its contribution to national, territorial and local development (Núñez, 2006, Núñez, Felix and Pérez, 2006), and for satisfying the technological demands of society it manages many substantive processes, of those which it stands out the management of science and innovation for their reach in the relationship that establishes the university with the environment.

The analysis of the bibliography related to the management of science and innovation in universities (Souza, 2002, Etzkowitz and Leydesdorff, 2000; Núñez, 2006) allowed to identify two directions of interest: the relevance and social importance of this process, and the foundations on which its management rests. Three elements are associated to the second direction: conceptualization of the object, conceptual models of knowledge production, and methods and tools management.

Taking into account the first element, the bibliography was reviewed (Arocena and Sutz, 2001, Souza, 2002, Etzkowitz and Leydesdorff, 200; Núñez, 2006), brought out that there are many concepts of management of science and innovation in universities, of global nature, but none specifically related to the area of knowledge of this research, so there is a gap in the bibliography and, therefore, there are not main guidelines that identify this process and its management.

The second component, conceptual models of knowledge production, is a current phenomenon that the university has transposed and incorporated into its theoretical conceptual system (Etzkowitz and Leydesdorft, 2000; Gibbons, Limoges, Nowotny, Schartzman and Trow, 1994; Núñez, 2006) trying to explain its links with society through the processes it manages.

Thus, there are six models of knowledge production that have been used to "interpret the university's technoscientific trajectories" (Castro, 2007) and have evolved from the linear model of innovation to the central-context, through national innovation systems SNIs), mode 1 and mode 2 of knowledge production and triple helix. Its study showed that there are positive aspects that should be fixed as antecedents of the research, and limitations, such as:

-Most of them assume a widen concept of innovation and the learning of the actors as a key factor of it, they are interdisciplinary, they emphasize the interdependent nature of the innovative processes that favor the work in networks and the formation of strategic alliances.

-They are general theoretical models, conceptual, which describe the processes of production of knowledge, but do not explain a system of knowledge well-structured and systematized that analyze and explain theoretically the university system and allow greater theoretical flexibility, methodological and practical management.

In relation to the management method, several published experiences have been studied in different universities (Argote, 2009; Belloso, Barboza, Salazar and Guerra, 2011; European University, 2009; Fernández, 2008; Valdez et al., 2008; Zúñiga , 2011; Rubio, 2006), from it the analysis concludes that:

-The general methods of management science have been used for the management of science and innovation in universities, and no specific methodological tools were found scientifically supported in this field.

-The published experiences consider and highlight some components of the system to the detriment of others, which limits the conclusions, due to the absence of certain interactions and relations of their own, so they do not consistently use the principles of systems theory.

From the analysis performed on theoretical research methods applicable to management systems for their refinement, such as systems theory (Bertalanffy, 1976; Wadsworth, 1997), the theory of constraints (Goldratt and Cox, 1993; Debernardo, 2008), the process approach (Ramirez and Garcia, 2009, Guerra, 2009), structural analysis (Godet, 2000) and the general theory of management (Koontz and Weihrich, 1984, Steiner 1996, Stoner et al., 2003), it was found that these alone are insufficient to perfect the management system studied, due to the great diversity of constituent elements of the same and the complexity of their functional and structural interrelations, so it is necessary to integrate them into from the essential contributions of each of them.

Exploratory research has been applied to understand the trend of university performance in science and innovation management, analysis of published literature, interviews with managers, and the authors' experience, it also corroborated the fact that these have low results in the main indicators, Say: publications, projects, awards because the tools are not enough to the management process elaborated under a theoretical- conceptional and methodological system, and the use of the general management techniques which are the bases of its improvement .

Based on the above mentioned in relation to the management of science and innovation in universities, it is concluded that: i) its properties and guidelines are not known because this process is not conceptualized, ii) the production models of knowledge are conceptual, general, that do not explain the methodological tools for the management of the process, iii) there is no a systemic methodology that integrates the theoretical research methods applicable to carry out the theoretical study of the management system of science and

innovation in universities (MSSIU), iv) international and national experiences are based on the general theory of management, so no specific methodological tools were found for this, and v) the experiences applied to the management of science and innovation (GCI) in universities have methodological limitations and an insufficient systemic character which underpin the fundamental contradiction of the research expressed on the one hand, on the need to improve the management of science and innovation in universities so that they fulfill their social responsibility in the current context and, on the other hand, the insufficient theoretical foundations and systemic methodological tools and to achieve it.

Therefore, the scientific problem lies in the existence of insufficient systemic theoretical and methodological foundations and flexible for the improvement of the MSSIU, which contribute to the improvement of its output indicators. In order to solve the problem, the general objective has been formulated: to develop a systemic, flexible, participatory and proactive management technology for science and innovation in universities, to improve its output indicators.

2. MATERIALS AND METHODS

The quantitative and qualitative paradigms have been used as a general methodology for this research, although with predominance of the first one. The main theoretical methods of investigation, that are: historical-logical, analysis and synthesis, inductive-deductive, hypothetical-deductive and modeling have been applied to understand the object of study in its development, its history and its logic, to discover the essential relations and general characteristics of it, to determine generalizations and to confirm theoretical formulations and to make its reproduction structural and functional simplified.

Considering that the object of study is a complex social process with the existence of a large number of variables, many of them outside the control of the researcher, a social experiment was developed, based on a single case study. The following instruments were used for the data collection: participant and covert scientific observation, questionnaire, semi-standardized interview, measurement and experiment, based on the informed consent of the interviewed.

The statistical analysis was focused on descriptive statistics, trend analysis and the method of moving averages to know the evolution of indicators before and after applied technology. A student's t test was used to verify that there were significant differences between the means of the indicators in the years 2008-2010, period where the proposed technology was applied, with respect to the years 2004-2007. The SPSS 19.1 (2013) was used for the use of these methods.

3. RESULTS

3.1. Synthesis and conceptualization of management technology

The object of study is a sociotechnical system (Baxter and Sommerville, 2011, Mumford, 2000, Chai and Kim, 2012; Ghaffarian, 2011; Patnayakuni y Ruppel, 2010) it consists of several components that interact with each other, it has objectives, takes the environment information and inputs, and among its elements are people, social, and technology, so a management technology is proposed for its improvement.

La technology is based on the systemic method and integrates the process approach, constraint theory (TOC), structural analysis and management theory. It consists of three phases: modeling and conceptualization of the MSSIU, modeling the management of the MSSIU, and synthesis of the management methodology, and it is characterized by being systemic, flexible, participatory and proactive.

In the first phase an exploratory study of the structure, functions, elements and links of the MSSIU is made to establish the preconditions and limitations of the general model of the MSSIU, which is conceptualized according to the methodology of Spedding (1975) cited by Wadsworth (1997), improved with two steps: the precision of the processes and the restrictions of their operation.

In the second, there is an integration of the components and particularities of the process, and describe and establish the flows in a specific model for management. It sets out the issues, including the management guidelines, the essential elements of the MSSIU study and the restrictions. It defines the premises, principles and requirements of management, and it models and describes the process in terms of logic, components and relationships.

The last phase is based on the cognitive basis of the theory of management to synthesize a methodological tool, and in its conceptualization are described the elements that integrate it to facilitate its application: name of the stage, objectives, actions that are carried out and probable method that is used (Koontz and Weihrich, 1984, Steiner, 1996, Stoner et al., 1996; Tristá, 2007).

3.2. Modeling and conceptualization of the MSSIU

The general model of the MSSIU was synthesized and conceptualized based on the information obtained on the object, and after establishing the conditions and limitations for its modeling.

-Demand-objectives-results of the system

The demands of the MSSIU are the economic, social, cultural, environmental problems presented by the organizations in the environment that can be solved by it. The demand has as variables its structure, volume, level of complexity and dynamics. The demand for the environment is named total or potential demand, the demand for which the MSSIU is designed is called design demand and the one that it can satisfy is named objective demand.

-System Limit

The limits of the MSSIU are its virtual walls, which include the university building (or part of it) and the locations where it carries out its activities on a regular basis.

-Environment of the system

The MSSIU has four levels of environment: university, municipality, provincial and generic (national and international). The first is where the system develops within its limits. The municipality environment defines demand and provides the MSSIU with an essential part of the resources. The last two influence indirectly. The environment has three variables: the environment for science and innovation, the capacity for structural, functional and physical resources, and the cognitive and volitional capacity in science and innovation.

The PEST analysis (Johnson and Scholes, 2004) revealed that the environment system is dynamic and with a higher degree of uncertainty, due to its complexity, and the dynamics of economic and social transformations that affect it.

3.3 System components

-Physical resources

This component, which includes infrastructure and material resources, tangible technological support - which do not intervene in the process directly - and financial, has as its mission to ensure logically the operation of the system. Its origin is in the inventory of the MSSIU's own resources and those of the environment, so the system must have the ability to locate and use them. This has as variables: infrastructure, technological resources of support, financial and inputs.

-Technologies

The technologies component includes both tangibles, which interact directly in the process and determine their quality (computers, laboratory equipment, etc.) as well as the intangibles; the organized and systematized technical knowledge that allows to effectively carry out the management of the MSSIU. Its inventory is made based on quantity, variety, quality, technical status, degree of updating and actual availability of them in the environment. This component has two variables: tangible technologies and intangibles.

- Actors

The actors, transformation agents, have the purpose of ensuring the voluntary, active and conscious participation of people with sufficient cognitive and management skills to develop and direct the process. The actors involved are teachers, workers, undergraduate and postgraduate students, and other actors involved in the investigative process who are not contracted, which are insufficient. Three dimensions are taken in order to assess their influence in the MSSIU: the dynamization of the actors (training, engagement and communication), the ability of the actors (will and consciousness) and the competencies of the actors (knowing and being able to do). These can be synthesized in the variable cognitive and volitional capacity of the actors.

-Structural and functional organs of management

This component represents the way in which the MSSIU organizes its management, it is the nucleus responsible for the transformation, and has the purpose to provide the system of "spaces" and the legal framework necessary to manage science and innovation.

Under an environment of legal, material and financial constraints to create formal management structures,

the MSSIU needs to manage through functional mechanisms, such as commissions, ad hoc groups, programs, lines of research, projects. This component has three variables: types of existing structural and functional bodies, the quality of the management processes, and the quality and relevance of the results obtained.

-**Essential processes and interactions**

The MSSIU processes are the main, science management and innovation; the second order: management of actors, technologies and physical resources; the strategic processes of general direction; support services: technical, computer, security and protection services; and the subjectives: formation and extension.

In order to have a value judgment of the MSSIU interactions due to the relations of its components and thus discuss its influence on it, a structural analysis was performed (Godet, 2000) using the 19 variables obtained from its theoretical analysis, and with that it was determined the variables of greater motricity and those of greater dependence for the development of the MSSIU, with several dimensions and indicators each of them, which indicates that the management system is sociotechnical, complex , open and dynamic.

-Inputs from the system

According to the previous analyzes, the MSSIU has inputs that enter to the resource gap, technological demands, physical resources, specific technological resources for science and innovation activity and actors. The diagnosis of the resources and demands of the environment and its precision as to its possible input is a starting task to fulfill the management.

-**Outputs of the system**

The final products of the MSSIU are scientific results, arbitrary scientific results, finished projects, awards, events, publications, patents, copyrights, financing and scientific, innovative, environmental, economic and social impacts.

This research uses the main indicators that the Higher Educational Minister (HEM) has established to evaluate the MSSIU: prizes, events, publications, projects, postgraduates and financing, because they provide a correct pattern to evaluate their progress and allow levels of comparison with the rest of the universities.

4. MODELING THE MANAGEMENT SYSTEM OF SCIENCE AND INNOVATION IN UNIVERSITIES

Once the management guidelines of the process studied were defined, the same as the essential elements that emerged from the MSSIU theoretical study and the constraints that limit its operation, together with the accuracy of the premises, principles and requirements, the system management model was synthesized, which is composed of: a) inputs: demands, available environment resources, premises, and other external factors, b) outputs in form of finished concrete results delivered to the environment and other unwanted ones, where some of them can be re-entered into the management system, c) all kinds of available resources in the resource gap, d) the dynamic and promoting nucleus of management, e) the specific components of the management, and f) the regulatory and guiding components for management. The core dynamiser and promoter of management is the responsible structure for the coordination of the MSSIU, which conceives the process, creates mechanisms for its operation, monitoring, control and evaluation, and for its continuous improvement. The components of the management cycle are conception and preparation, diagnosis, planning and organization, implementation, and evaluation, adjustment and improvement.

The regulatory and guiding elements are the constraints, principles and requirements.

The harmonious and essential integration and interconnection of the components of the MSSIU to obtain an end gives it its systemic character, and the conformation of activities concatenated with the inputs and outputs of the process approach. The proactive is based on the anticipation of problems by the MSSIU, through a systematic study and monitoring of the environment, and flexible because of its ability to adapt and change to improve processes. The participatory nature is in the capacity of self-management and real participation of the actors in the processes. The succession of the stages following a spiral shows the tendency to development, to improvement, from a constant evaluation, adjustment and improvement of the process.

5. SYNTHESIS OF THE METHODOLOGY OF MANAGEMENT

The methodology is integrated by seven phases: a) conception and general preparation of the process, b)

characterization of the system environment, c) accuracy and objectivization of system capacity, d) design of planning elements, e) design and creation of organizational elements, f) implementation, and g) evaluation, adjustment and improvement. Several stages have to be executed in each phase.

Phase I: the Management Group (MG) is created, the objectives, scope, principles, requirements and restrictions are defined to govern the process, the material conditions are specified and / or created, minimum cognitive, volitional and organizational requirements, the members of the Scientific Staff (CS) and the Principal Staff (PS) or similar structures, and disclose and training activities are carried out to the main persons.

Phase II: the selections of the organizations of the territory to be prioritized, identification of the sources of information and main informants, elaboration of the instruments that will be used, the creation of the necessary material, organizational and human conditions, and afterwards, the production of the corresponding reports.

Phase III: this is where the capacity of the MSSIU is evaluated to meet the demands of the environment. The procedure is similar to the previous phase. At the end of the year, there is a stock of resources of all kinds that the university has for management.

Phase IV: the actions to be developed are planned in this phase. Restrictions are determined and they limit the operation of the MSSI, prioritized, objectified and hierarchized of the demands; and the elaboration of the mission, vision, strategic objectives, policies, priorities, scientific and technical programs (STPs), objectives and year schedule for the management.

Phase V: the system of mechanisms and management team is designed here: areas and research groups, dynamic structures, etc., and the directions to the different levels give legal body and put them into operation through the creation resolutions with its objectives and its functions, staff and premises designation, logistical support, etc.

Phase VI: Scientific and Technical Programs (STP) are convened and I & D projects, innovation, management and scientific and technical services are developed. The planned actions are fulfilled, while the dynamization teams evaluate the fulfillment of the plans, and they train and advise the actors.

Phase VII: its aim is to evaluate quantitatively and qualitatively the results, detect the deviations and make the necessary changes or adjustments.

6. DISCUSSION

As for the output indicators of the MSSIU, a trend analysis of its behavior was carried out in the period 2004-2010 and its respective moving averages for three years. Both curves show that the six indicators grow steadily and more strongly in the period 2008-2010, the technology was implemented over this period, and the technology was not applied during 2004-2007.

To demonstrate that the growth in the indicators evaluated above do not depend on the possible increase of the professors, the indexes of these by professor were determined in the period 2004-2010 and by means of a calidograma is corroborated that they present a sustained increase in their indexes.

To evaluate the dynamics of the changes, a vector analysis was made with the indices of the indicators in the analyzed period. The review of the resulting speed vectors found that the speed which the indices of the indicators were higher in the period 2008-2010 than the period 2004-2007, it confirms that in the last three years, where the management technology was applied, the indicators improved in a significant way respect to the before years.

In order to verify the above assertion, the means of the indicators between the years 2004-2007 and 2008-2010 were compared using Test T. The values of the level of significance obtained are less than 0.05; so it can be affirmed that there are significant differences between the means of the indicators in the years 2008-2010 with respect to the years 2004-2007; this confirms, with a level of confidence of 95 %, that the applied management technology contributed to the improvement of the output t indicators of the system of management of science and innovation in the universities.

7. CONCLUSIONS

1. In the study of the bibliography and the object, there was not found a technology where the existing knowledge for the university management of science and innovation is systematized, allowing to analyze, conceptualize and perfect this process and consider its systemic, flexible, participatory and proactive.

2. The strategic importance of strengthening the management of science and innovation in universities was corroborated in the current context; however, the analysis of the results showed that these were poor, motivated by, among other factors, the lack of a technology for their management, which confirms the importance of having these tools to adapt to changes in the environment and achieve effectiveness In its management.

3. The proposed management technology is a novel method to perform the MSSIU theoretical analysis and the synthesis of its management methodology, since it integrates, based on systems theory, a set of theories, approaches and methods associated with management of these systems, such as: process approach, constraint theory, structural analysis and management theory.

4. The MSSIU modeling allowed its conceptualization and revealed its components, its sociotechnical nature, complex, dynamic and open character, complex and unpredictable nature of its environment and its constraints, and with it, to elaborate the MSSIU management model that is based on continuous improvement, and is energized with the regulatory and guiding components for the management, where of the methodology is synthesized.

5. The synthesized methodology for the management of the MSSIU is a guide to concrete practical work concrete to be transformed according to the needs of the system, as it integrates its particularities defined in previous theoretical studies and summarizes in seven sequential and iterative phases a system of actions related to the characteristics and technical-organizational and functional conditions of the universities, which facilitates this applied methodology.

6. The results of the application of management technology in the selected university showed a significant increase in the indicators evaluated in the period 2008-2010 with respect to the previous stage, which demonstrates the effectiveness of it and made possible to verify its real capacity for improving the output indicators of the MSSIU, and its feasibility and convenient use as a methodological tool to improve it.

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