Pyramidal research structures: design and operation. An experience in industrial engineering

Estructuras piramidales de investigación: su diseño y funcionamiento. Una experiencia en la Ingeniería Industrial

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ABSTRACT
The article presents a methodological approach that employs a pyramidal structure to organize research activities between students and teachers. The application of a pyramid structure to research management reveals a transformative conception, particularly in its dual-flow mechanism for knowledge sharing (bottom-up and top-down). The importance of this approach lies in its ability to address deficiencies in hierarchical knowledge transfer and improve the efficiency of research outputs in academic settings, thus bringing new perspectives to the cohesive integration of different levels of research activity. The practical relevance of the model is substantiated by the findings derived from capstone exercises, ensuring a sound basis for the proposed model. The research employs a descriptive instrumental case study methodology, underpinned by the concept of teamwork, guided by a tutor or overall coordinator.
Keywords: pyramidal; scientific research; knowledge; hierarchical levels.

RESUMEN
El artículo muestra un enfoque metodológico novedoso que aprovecha una estructura piramidal para organizar las actividades de investigación entre estudiantes y profesores. La idea de aplicar una estructura piramidal a la gestión de la investigación revela una concepción transformadora, particularmente en su mecanismo de doble flujo para el intercambio de conocimientos (ascendente y descendente). Su importancia radica en abordar

las deficiencias en la transferencia jerárquica de conocimientos y mejorar la eficiencia de los resultados de investigación en entornos académicos. Aporta nuevas perspectivas para integrar de forma cohesiva diferentes niveles de la actividad investigativa. Los datos de los ejercicios de culminación de estudio respaldan los hallazgos, lo que garantiza una base práctica sólida para el modelo propuesto. La investigación emplea una metodología de estudio de caso instrumental descriptivo, a partir de la concepción de trabajo en equipo, bajo la dirección de un tutor o coordinador general.
Palabras clave: pirámide, investigación científica, gestión del conocimiento, nivel jerárquico.

Introduction

The pyramids have always been an undeniable attraction. In some cases, because of the mysteries and secrets they still hold, as tombs and repositories of valuable treasures belonging to not a few famous pharaohs or kings of ancient Egypt and other regions of the planet. More recently, pyramids have been discovered to have many uses, such as medicine, sports, food preservation, water treatment and, to a lesser extent, the management of various teaching, learning and research processes.

The subject of the design and operation of pyramidal research structures has received little attention in the literature consulted. According to the authors, there is a contradiction between what has been achieved, with the location of the contributions derived from the research activity by hierarchical levels, and what has not been achieved, due to the lack of indications or actions for the transfer of these contributions in the form of scientific knowledge between levels [1, 2, 3].

In line with the above, the objective pursued is based on the need to share the experience of designing and operating a pyramidal research structure as a reflection that demonstrates the organization and development of a doctoral training process and its continuity over time.

It develops a novel methodological approach that takes advantage of a pyramidal structure to organize research activities among students and faculty. Its importance lies in addressing deficiencies in hierarchical knowledge transfer and improving the efficiency of research outputs in academic settings. Practical recommendations for improving research efficiency are proposed. Data from diploma, masters and doctoral theses support the findings and provide a sound practical basis for the proposed model.

The scientific, pedagogical and technical advice is supported by the results of the team work of specialists from the Centre for the Study of Management Techniques (CETDIR) of the Technological University of Havana (CUJAE), with the participation of executives from the Ministries of Construction (MICONS), Informatics and Communications (MIC) and Agriculture (MINAGRI), who

develop their research activity in this institution. As a result, the necessary functioning of the pyramid was achieved, in order to guarantee a rational use of the available resources, the production of scientific knowledge and the contribution to the formation and development of the scientific character of the research activity.

Methods

In accordance with the qualitative nature of our research, based on a descriptive instrumental case study, we developed the analysis of several theoretical approaches and the evaluation of results derived from related research, with the application of techniques such as the SWOT matrix, the Ishikawa, the checklist, the comparative analysis, among others. It was very useful to take the best experiences of successful application of the results of consultants and advisories, work practices, diploma, master and doctoral theses.

Based on what was mentioned, theoretical research methods such as analysis-synthesis, induction-deduction, historical-logical and systems approach were applied, and among the empirical methods, direct observation. The methods were adapted to the characteristics of the work, allowing for greater objectivity in the evaluation of the results. During the period analyzed (approximately two years), several research workshops were held to select, implement and evaluate the results of the application of various procedures, methodological proposals, strategies, methods and techniques for data collection and processing, all of which allowed the consolidation of the upward and downward flow of scientific information, or what could be understood as the exchange of knowledge among the participants, organized by hierarchical levels. As a result, the necessary functioning of the pyramid has been achieved to ensure the rational use of available resources, the production of scientific knowledge and the contribution to the formation and development of the scientific character of research activity.

The following section will describe the particularities of the research skills training process for each group of students in the Industrial Engineering degree and the Master's degree in Management, during the development of two work experience subjects. The subjects were organized in two teams, with four students each one. The students received technical and methodological advice in the design, preparation and defense of their diploma thesis. This made possible to receive and contribute scientific knowledge to the completion of the information required for the research being carried out at that time by four master's students, who were able to maintain a direct link with the contribution of information downwards towards the development of the diploma work, an activity that led to an upward flow of scientific knowledge as a contribution to doctoral research, the graphic representation of which will be shown below.

Results

The analysis of the results provided valuable experience, which is summarized in the answers to the following questions:

1.-What is a pyramid?
2.-What is research pyramid?
3.-How is the research pyramid structured?
4.-How should the research pyramid work?
5.-What were the main contributions of each research inserted in the pyramid structure?
6.- How the use of pyramidal structures contributes to the successful development of the research activity?

The answers are the following ones:

1. - What is a pyramid?

According to the dictionary of the Spanish language of the Royal Spanish Academy (updated 2023) pyramid comes from the Latin *pyrămis, -ĭdis*, and this from the Greek *πυραμίς, -ίδος pyramís, -ídos*; properly 'pyramid-shaped cake of wheat flour', derived from *πυρός pyrós* 'wheat flour'. In its first meaning it is defined as asolid with any polygon as a base, and whose faces, as many in number as the sides of that polygon, are triangles that meet at a single point, called vertex. Its second meaning, it is a monument, usually made of stone or brick, in the shape of a pyramid [4].

On the other hand, the *Encyclopaedia of Meanings* defines that "A pyramid is a figure that has a base in the form of a polygon, whose lateral faces are triangular in shape and are joined at the same vertex. It is a three-dimensional geometric structure in the form of a truncated cone with a flat base" [5]. Twenty-four papers were examined in the context of the reference search for the pyramid design on several online sites. This study is shown in figure 1.

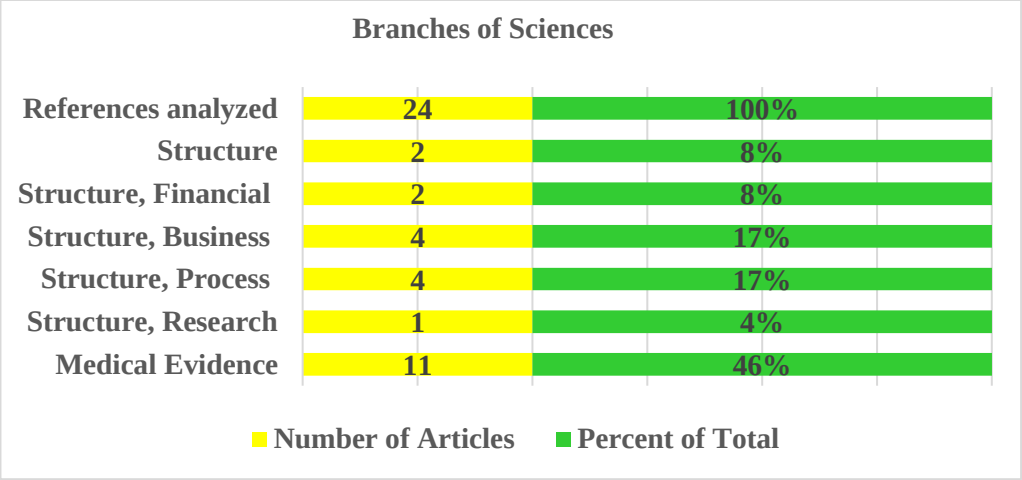

Fig. 1 - Analysis of articles on online research pyramids

46% of the articles were related to the study of evidence for the medical sciences and 54% were mainly used to structure or prioritize processes, business structures, and financial structures, among others. The use of pyramids in geometry and architecture is well-documented, with additional applications including the study of scientific evidence, for example, Haynes pyramid and the hierarchy of human needs, Maslow's 1943 and Kalish's 1977 pyramids, for the hierarchical organization of legal rules such as Kelsen's pyramid, the theory of the pyramid of accidentality in Bird's. They are also used to differentiate population groups, organizational structures, among other [6, 23].

2. What is a research pyramid?

There are many ways to organize different activities in a pyramid structure, as there are several online providers of pyramid design services. There are also different definitions of pyramids, based on one of the most elementary forms of this geometric figure, with a square base, as old as mankind itself. From this point of view, the research pyramid is therefore one of the many ways of organizing a system hierarchically by levels, distributing and transferring the ascending, descending or transversal flow of scientific knowledge management derived from the research activity, developed in a given context. In this system, each activity brings scientific knowledge to its higher level of research, and this higher level brings direction, control, advice and guidance to its lower level of research.

3. - How is the research pyramid structured?

Research pyramids, as it was already mentioned, are characterized by a "hierarchical and graded organization" of the different forms of presentation of the results of scientific research, including projects, reports, articles, theses, etc.

In the case of theses and their hierarchical presentation, it is recommended the following organization:

1st section (apex or vertex): Doctoral thesis
2nd section (apex or vertex): Master theses
3rd section (apex or vertex): Diploma theses
4th section (base of the pyramid): Internships (work practices)

For a better representation and understanding of the content of the research pyramid structure, it is crucial to specify the first names and surnames of their authors for each level and their research topics. This way it is easy to know the behavior of the research lines and their possible results when more than one pyramid is generated.

4.- How should the research pyramid work?

As a fundamental principle, research pyramids should be made up of research activities that are interrelated and contribute to a specific line of research or to a research project. No "last minute changes to a plan" are allowed because that methodological incongruity would limit the actual functioning of the pyramid in question. This requires a careful consideration and selection of the research topics and corresponding authors to be included in each hierarchical level of the pyramid. If the research line or the project is related, for example, to the "development of organizational capacities", the topics selected for each level must necessarily contribute to this line or project and be interrelated as a system in order to guarantee an adequate upward and/or downward flow of scientific knowledge management. The following figure is a real example of how the pyramid was structured and used in a certain period of time with the line of research that is part of the Organizational Capacities Development Group, where several CETDIR professors worked on the result (Figure 2).

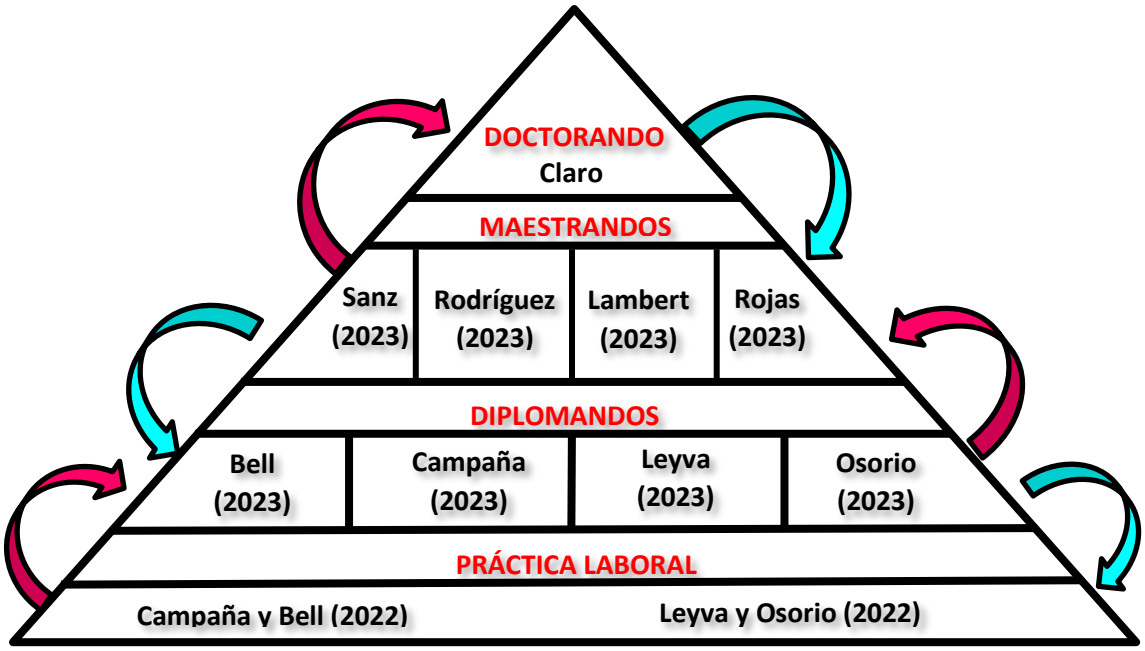

Fig. 2- Hierarchical order of the applicants' names.

This structure allows a flow of information, represented in the figure by the red arrows pointing upwards, which provide the information required by the different levels of research and the blue arrows pointing downwards indicating the direction for consultations and/or tutorials.

The structure also guarantees a better organization of the scientific research activity for each line of research, with the systematic application of the knowledge acquired during the degree studies and developed during the professional practice, as well as the necessary deepening in the study of the theoretical and methodological foundations of the topic presented, making it possible to articulate in a coherent way with different approaches and points of view, achieving technical and methodological organization in accordance with the logic of the content to be researched. Alternative solutions were presented, together with the proposed actions to address the current deficiencies related to the shortcomings identified in each topic. It also shows evidence of the systematization of the research skills developed by the authors in a relatively short period of time and their relationship to the relevance and timeliness of the works presented.

It is important to consider that the whole process was a training modality for each of the candidates, as they were trained in how to give guidance to their lower levels, how to manage scientific knowledge, how to use each technique and research tool, how to design, write and defend the thesis, as well as interacting in the role of tutor and opponent.

5.- What were the main contributions of each research inserted in the pyramid structure?

As in any scientific research process, before proposing a solution to a specific problem, it is necessary to specify what the scientific contribution should be for the achievement of the proposed objective as a possible solution to the identified problem. This idea is represented in tables 1 and 2.

Table 1 - List of authors, topics and problems identified and main contribution in their diploma theses.

Authors	Bell (2023)	Campaña (2023)	Leyva (2023)	Osorio (2023)
Topics	Proposal of actions for management by competencies of MICONS workers.	Proposal of actions to improve the management of GEICON training process.	Proposal of actions to improve performance management in the SOMEC company.	Proposal of actions for the management of the agricultural performance extensionism in the IIPF.
Identified problem	Deficiencies in the performance of MICONS workers.	Insufficient management of the training process at GEICON.	Insufficiencies in the management of work performance at SOMEC.	Insufficiencies in the management of agricultural extension performance in IIPF.
Main contributions	The competency map based on the requirements established in the ISO 10015: 2019 standard. Quality Management — Guidelines for competency management and people development. Second Edition. All of this, supported by a plan of actions and methodological indications for its implementation.	A model of the training process in Business Process Visual ARCHITECT 4.0 simulation, distributed by managers and accompanied by an improvement plan defined by the PHVA cycle.	The presentation of performance management model with three stages, accompanied by a proposal of actions to improve job performance management. Taking as reference the proposal of Molina (2012).	The presentation of a performance management model in agricultural extensionism, composed of four stages, accompanied by an improvement action plan.

Table 2 - List of authors, topics, identified problem and main contribution in Master's degree program

Authors	Lambert (2024)	Rodríguez (2023)	Rojas (2024)	Sanz (2023)
Topics	Procedure for improving the performance of the staff in SOLINTEL, S.A company.	Procedure for improving the management of the training process for staff and workers of the Construction Materials Business Group, GEICON.	Strategy for increasing export management in the Assurance and Comprehensive Livestock Services Company, EASIG.	Procedure for updating position profiles by competencies of MICONS staff.
Identified problem	Insufficient development of management skills in the performance of SOLINTEL, S.A. staff.	Insufficient management of the training process at GEICON.	Insufficient export management in EASIG.	Deficiencies in the performance of MICONS cadres.

Main contributions	The proposal is based on a training planning, based on the four stages of the cycle proposed by Cuesta (2010), taking as reference the three stages proposed by Leyva (2023), all with a contribution approach o improvement for management skills to optimize the work performance of the staff.	Presentation of a management model of the training process based on the modeling presented by Campaña (2023), taking as design criteria, the four stages of the training cycle proposed by Cuesta (2010), concluding in a procedure adjusted to the NC- ISO 9001: 2015.	Presentation of a COMEX strategy to improve business performance taking as reference the work model applied for the strategic design of Claro (2018) and the four stages proposed by Osorio (2023), based on the improvement according Wheelen&Hunger Model (2007) and Resolution No. 220 of 2022 of MINCEX. All of this, based on a training program to improve the performance of COMEX personnel.	A position profile by competencies is presented, based on the process map presented by Bell (2023), taking as criteria the requirements established in the ISO 10015: 2019 standard. Quality Management - Guidelines for competency management and development of competencies. Second Edition and work policies with state and government officials. The procedure was adjusted to NC-ISO 9001: 2015.

As its shown, the application of the pyramidal research structure, used as a methodological tool for the development of the research activity of students, contributes to the achievement of a successful exchange of scientific knowledge in accordance with the results obtained in each thesis.

6.- How the use of pyramidal structures contributes to the successful development of the research activity?

The principal contributions of the application of the pyramid to the successful development of the research activity are mentioned below:

1. The study, evaluative analysis and synthesis of the theoretical and methodological bases, in each of the theses presented, led to the definition of the stages of the management of the training process, as well as the determination of the essential components of training.
2. It is determined that the adequate management of the training process is linked to the development of productive forces and, therefore, to the increase of economic efficiency in business organizations.
3. It is evident that the management of scientific knowledge and information occurs within a pyramidal structure of research with hierarchical levels. The flow of knowledge and information is not only ascending and descending, but also flows transversally. This is due to the fact that research with different themes but related to the same

line of research or project feed each other. This is because the theoretical and methodological foundations, as well as the techniques and tools used, become referents and/or constructs.

4. It is concluded that the work that contributes most to this research pyramid is that of Rodríguez (2023), as it proposes an improved training process management model based on the four stages proposed by Cuesta (2010), and includes the aspects dealt with in the other research theses.

Possible limitations to the successful implementation of this experience could be:

- Insufficient methodological preparation of the researchers involved in the process.
- Lack of knowledge about the correct functioning of the pyramidal structure.
- Research designs with methodological flaws that affect the functioning of the designed pyramidal structure.
- Methodological inconsistencies due to the lack of correspondence between the topic formulated and the line of research of the selected project.
- The occurrence of subjective situations that affect the conception of the research activity, such as lack of motivation, lack of interest, rejection, etc.

Discussion

The process of designing the pyramidal structure of reference was accompanied by the necessary application of the aforementioned theoretical and empirical methods. This made possible to verify the relevance and effectiveness of the proposal presented, whether in projects or lines of research. In the first case, it also demonstrated the interaction between the different hierarchical levels established and the flow of scientific knowledge that is created and transferred.

It is acknowledged that the doctoral candidate represents the optimum level of interaction, not merely due to their superior position, but also because of the possession of the capacity to strategically manage the knowledge of the other levels, directing the design ideas. It is further acknowledged that the doctoral candidate occupies a pivotal role for facilitating teamwork among their peers, guiding their investigative endeavours, and ensuring the attainment of satisfactory results. In addition to these responsibilities, each tutor assigned to a lower level is expected to follow this step in order to determine the information needs of each applicant:

- The applicant must be able to perform adequately in the development of scientific research.
- The applicant must have knowledge of the methodology of scientific research, of the guidelines given and the indicative documents for the design of degree theses.
- The applicant must have an appropriate research work strategy, supported by planning in Project or another similar software, in order to reduce delays or deviations.
- It is imperative to establish and maintain a constant feedback process, ensuring the completion of each research project in a satisfactory manner at each one of the planned stages. Furthermore, it is essential to ensure that the progress of projects is presented in a satisfactory manner.
- In order to obtain valid results, it is crucial to possess a comprehensive knowledge of the possible techniques and diagnostic tools to be used in each topic. This will ensure greater acceptance and closer alignment with the reality of each identified problem.
- It is imperative to be cognizant of the inherent vulnerabilities and potential hazards that compromise the pyramidal research structure, with the objective of formulating the most efficacious measures to counteract them.

The importance of selecting students aspiring to a diploma thesis from work practice is confirmed by experience developed with students of Industrial Engineering, as they are prepared in the methodology of research, consolidating the knowledge acquired during the degree course.

Conclusions

1. The value of using the pyramidal research structure as a tool for the design of a scientific research process, differentiated and interconnected by the flow of information generated upwards and downwards between each hierarchical level, is evident.
2. The professional training of each researcher participating in the pyramidal research structure makes possible the management of scientific knowledge to be solid and coherent, leaving no room for deficiencies that affect the fulfilment of the stages of the research carried out. The closure of each stage can be determined in correspondence with what was planned in the methodological design.
3. The systematization of the methodological advisory work in scheduled working meetings makes it possible, largely, to achieve the desired transformations in the scientific research process and for the members located at each hierarchical level of the research activity to present the

expected results. In this sense, the experience and professionalism of the tutors play a decisive role.

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Conflict of interests

The autors declare there is no conflict of interests.

Contribution of the autors:

Ernesto Edelberto Hernández Calderín: Conception, proyection and conduction of the investigation. Contribution of practical experiences. Design proposal of tables and figures. Redaction of the article, critic revision of the content and final approbation to the published version.

Ricardo Claro González: Significant contributions to the idea and design of the study. Re-design of tables and figures. Critic revision of the article's content and develop of the bibliographic revision.

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