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Conformation of an Astrobiology Interdisciplinary Research Group: The "Team Killalab" Case Study †

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Abstract: The development of new technologies in recent years has highlighted interdisciplinarity as a tool to solve complex problems faced by scientists and engineers in research work. Worldwide, the area of space science, specifically astrobiology, has had more than 25 missions with high technological development and economic returns. However, the success of interdisciplinary teams requires collaboration, responsibility, and leadership on the part of all members to prioritize the main objectives of the research. Likewise, the formation of interdisciplinary teams can be affected because there is little information about the strategies and tools that recognize the opportunity for constant interaction between subjects from engineering and science. Using a known methodology based on other recent proposals, we include a description of the conformation and behavior of a research team and an analysis of interdisciplinarity through the interrelation and level of dependence of the existing subject categories in the "Killalab" team. In this research, we present the ensemble interdisciplinary group "Killalab" and its implications for the realization of astrobiological investigations.

Keywords: astrobiology; interdisciplinarity; subject categories; Killalab

1. Introduction

With the advance of knowledge and the complexity of problems, the need to involve several disciplines instead of one has arisen. In this way, the development of interdisciplinary teams to address contemporary technological and scientific challenges has increasingly been recognized [1,2].

The last approaches that investigated interdisciplinarity were based on quantitative methodologies. Many authors used the clustering of citation patterns [3]. Those bibliometric studies of interdisciplinarity were based on machine learning algorithms in an attempt to understand the fine-grained details of interdisciplinary research in big-data analysis [4]. However, those approaches do not always work when studying the formation of a research team in a real-life context. It is necessary to know what are the weaknesses and factors that can affect the success of the formation of interdisciplinary teams [5]. From a different point of view, some studies that have measured the success of interdisciplinarity have underlined that the publications with the greatest impact have come from collaborative teams and not from monodisciplinary teams [5].

Research in astrobiology is a clear example of interdisciplinarity since it requires interactions between various disciplines such as biology, astrophysics, chemistry, geology, and engineering, which are applied to an understanding of the origin, evolution, and detection of life in the universe [6]. However, although there are many studies that have measured the interdisciplinary and curricular proposals put into practice in student groups, to date, little research has provided information on the development of interdisciplinary research teams [7].

Currently, university students receive specialized training in a particular discipline and rarely interact with students from other disciplines. It is necessary to reinforce a promotion of interdisciplinary collaboration, since this provides the means to think innovatively and solve problems, not only for the industrial sector but also on the level of large projects such as what astrobiology implies. An investigation of the formation of an interdisciplinary team for astrobiology experiments in a real research context will provide keys to the improvement of the performance of research teams [5].

This article examines the interdisciplinarity inside the team "Killalab", which develops astrobiology research. The results will help in annotating (for interdisciplinary teams in other fields of research) how interactions have to be emphasized to eliminate barriers and get better results.

2. Interdisciplinarity

Interdisciplinarity is the integration of information, data, techniques, tools, perspectives, concepts, and/or theories between two or more specialized disciplines to advance in the understanding of complex problems whose solutions are beyond the scope of a single research discipline [8]. Interdisciplinarity arises due to technological growth that demands solutions that require the linking of different disciplinary fields to answer more complete questions or facilitate the application of knowledge in a specific area [9].

Multidisciplinarity involves several different academic disciplines that investigate a topic or problem with multiple disciplinary objectives. The research process occurs in parallel to compare results, but without integrating disciplinary knowledge [10]. This last aspect is important because it differentiates interdisciplinarity from multidisciplinarity in terms of the integrating-disciplines aspect, which occurs often in interdisciplinarity as opposed to multidisciplinarity, where the disciplines are only present and interaction only occurs within each discipline.

The collaboration of different disciplines has always been a challenge that has involved the creation of scientific culture. The critical factors found for interdisciplinary work have been paradigms of the separate scientific disciplines, the capabilities of each team member, and the institutional context of research and team management [11]. Integrating the diverse experiences of the participants is the key to success, and this is evident in the results of research and collaborative publications [10]. Associated with this success is the quality of the research, which can be a factor; the time and the resources that the experiments take; approval of the conclusions from different monodisciplinary points of view; and arrival at a new holistic understanding of the problem investigated.

Despite the progress of research, interdisciplinarity is not yet applied by students or researchers who have already been trained. Interdisciplinary education programs are required to put this interconnection of knowledge into practice. Many programs handle an approach from multidisciplinarity to interdisciplinarity [12].

3. Astrobiology as an Interdisciplinary Science

Astrobiology is the study of life in the universe (according to the definition of the National Aeronautics and Space Administration (NASA)), which covers the origin, evolution, distribution, and future of life in the universe as its roadmap is exposed [13]. There are several benefits to astrobiology, from its interdisciplinary nature as a new tool for the formation of multiple research teams to the discovery of new habitable scenarios in the solar–planetary system neighborhood.

At the beginning of 1988, astrobiology was not considered to be an interdisciplinary science [10]. With the progress of space missions, the interdisciplinarity of astrobiology has become known as inherent because it requires the conjunction of biologists, chemists, astronomers, and engineers to address experiments that aim to solve questions about life in the universe (Figure 1), e.g., whether terrestrial microorganisms can survive in the conditions of deep space.

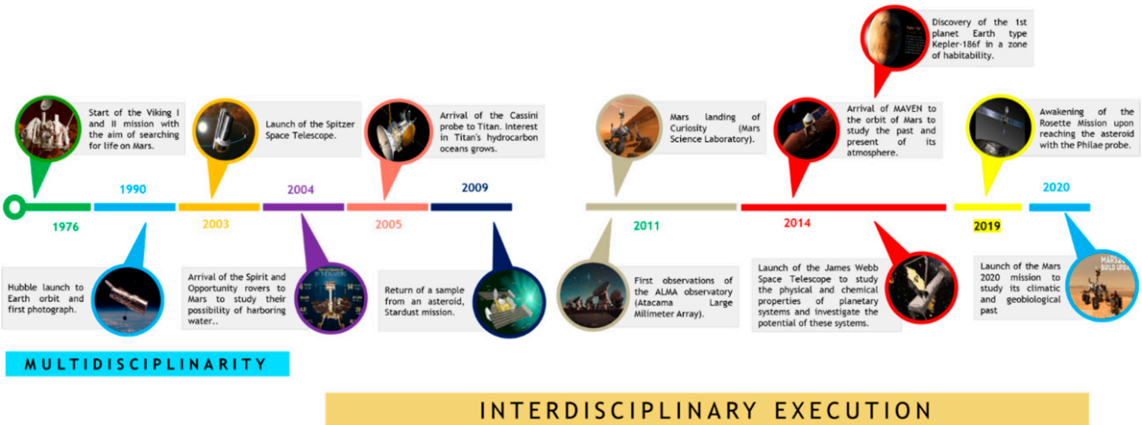

Figure 1. Astrobiology timeline with multi- and interdisciplinary approaches: until 2003, astrobiology was multidisciplinary, but with the advance of space missions, since 2008, it has become a science with interdisciplinary execution. Its success depends critically on the close coordination of various scientific disciplines and programs, including space missions planned for the future.

Development of Interdisciplinary Teams in Astrobiology

Interdisciplinarity in astrobiology has made possible the development of new technologies that could not have been achieved without the intervention of biology, chemistry, physics, software engineering, mechatronics, and telecommunications [14]. Such was the case with the Mars Science Laboratory (MSL), whose main objective was to reach the surface of Mars, characterize the geology of the landing region, investigate planetary processes that influence habitability, and characterize the broad spectrum of surface radiation [15]. The mission of the MSL has been executed from 2012 to the present day by conducting experiments designed by an interdisciplinary team that has included the Curiosity rover, a multisensor radioisotope generator, a parachute, an entry and exit system, and a launcher. However, the experiments have focused on the operation of Curiosity (which included the payload of the mission), and it was precisely the diverse nature of the data required to address the habitability of Mars that led to the realization of a complex charge design used with an integrated quadrupole mass spectrometer (QMS), a gas chromatograph (GC), and a tunable laser spectrometer (TLS) to analyze the atmosphere and gases developed from rock and soil samples (SAMs). For this, interdisciplinary groups of more than 400 international researchers were formed: they worked in groups and they had the ability to criticize and openly communicate about the work capacity of the engineering experts and vice versa (communications that were later gathered by the Project Science Group) [16].

In the case of the MSL mission, the Project Science Group (PSG) was a project management tool. Thus, the PSG brought together all specialists to develop an integrated activity plan. In this scenario, the working groups were allowed to meet privately and then interact and participate in planning [15]. In short, an organization with a high level of systematization and an integrating culture is favored in the work of an interdisciplinary team.

4. Methodology

4.1. Case Study

Team "Killalab" ("Killa" means "moon" in the Quechua language) is a research group of the Scientific Society of Astrobiology of Peru that officially emerged in 2017 after the Lab2Moon Contest organized by the Team Indus Foundation, which was a finalist in the Google Lunar XPRIZE. The team received a grant from the National Council of Science and Technology in Peru in 2018 to carry out its research. The team started with a small group of scientists, and they led the conformation of the entire team, taking into account the considerations described below. The principal location of the team was Lima, Peru.

This study met the conditions proposed by Yin in 2003. This means that it contained the nature of research questions such as how and why; it did not have control over the participants; and finally, but not less importantly, this phenomenon developed in the context of real life [17].

4.2. Research Settings

Team Killalab, which developed a project in astrobiology, had to use techniques and processes from different disciplines "to study the effects of radiation from the outer space environment on cyanobacterial biofilms isolated from the Peruvian high Andean ecosystems using an autonomous aerospace minilaboratory". The conformation process of the team had the following considerations:

- A careful and strategic selection was made of the necessary disciplines and individual participants capable of occupying those positions [18]. These team members had to possess the characteristics of vision, dedication, reliability, ability to take responsibility for their limitations or errors, and ability to solve problems [19]. Thus, the members of the interdisciplinary team were expected to cooperate, share leadership, and demonstrate responsibility;
- The team members shared a commitment to completing the tasks required to meet the principal goal;
- Specific objectives for each scientific discipline were established after the complete conformation of the members of the team and after determining the principal goal in order to keep the team focused on the tasks that would solve a single problem, as other authors have suggested [20].

4.3. Data Collection

To examine the effect of the interdisciplinarity within the research group, the present qualitative study used observations and descriptions of the conformation of the members (stakeholders), the specific objectives of each discipline, the subject categories involved, and the relationship between them. Those that were considered were scientific discipline boundaries that have been used in other studies as a measure of the degree of interdisciplinarity [4].

5. Results and Discussion

5.1. Team Killalab Discipline Conformation

The research team was composed mainly of Master's and Ph.D. researchers and young graduates, some of whom did their thesis on the specific objectives from the general proposal. The disciplines present in the research group were chemistry, biology, physics, electrical engineering, mechanical engineering, and computer science. The team was comprised of 13 members.

In the project, there was a principal investigator (PI) whose function was to direct the team members to establish common specific objectives of the research by discipline. A PI in interdisciplinary research can come from any discipline as long as he/she possesses required experience relevant to the research objectives and can bring together the unique and diverse perspectives that are fundamental to achieving these objectives [21]. In the Killalab team, the PI came from science.

Team meetings were an essential tool for communication and knowledge exchange. The maintenance of the approach and the execution of the study were complemented by the establishment of deadlines for the research milestones.

5.2. Specific Objectives and Interaction of Tasks

For the realization of the astrobiological research, specific objectives were proposed by discipline as a strategy to maintain team focus on one goal (Table 1).

Each discipline also had tasks in meeting the specific goals of the total research. Manufacturing the payload (minilaboratory), which will go to the space, was considered to be a milestone. We used the tasks of this project to show the dependence and communication that existed between disciplines. This is represented in Figure 2 as mechanical tasks (M-1, -2, -3, -4, -5, and -6), electronic tasks (E-1, -2, -3, -4, -5, -6, -7, and -8), science tasks (S-1, -2, -3, -4, -5, and -6), and computer science tasks (P-1, -2, and -3). Within the scientific tasks were the disciplines of chemistry, biology, and physics. This figure also represents the communication strategy between scientific disciplines in order to carry out their corresponding tasks. After a consensus, the next task was continued.

The task interactions that had the most significant impact on the realization of this stage were science–mechanics and mechanics–electronics, followed by electronics–computer science. Likewise, it is important to mention that identifying all of the areas of study and the related sciences and engineering allowed for focus on the main objectives of the team and the experiment.

Table 1. Specific goals from each discipline involved in team Killalab.

Discipline	Specific Goals
Biology	Study of the survival of cyanobacteria in the extreme conditions of space
Chemistry	Study of the chemical modification of the protective pigments of cyanobacteria
Physics	Evaluation of the physical conditions of a payload that can resist total components
Electrical engineering	Design of the electronics of the payload (minilaboratory)
Mechanical engineering	Design of the mechanics of the payload (minilaboratory)
Computer science	Gathering of data from simulations and real ultraviolet radiation exposure in outer space

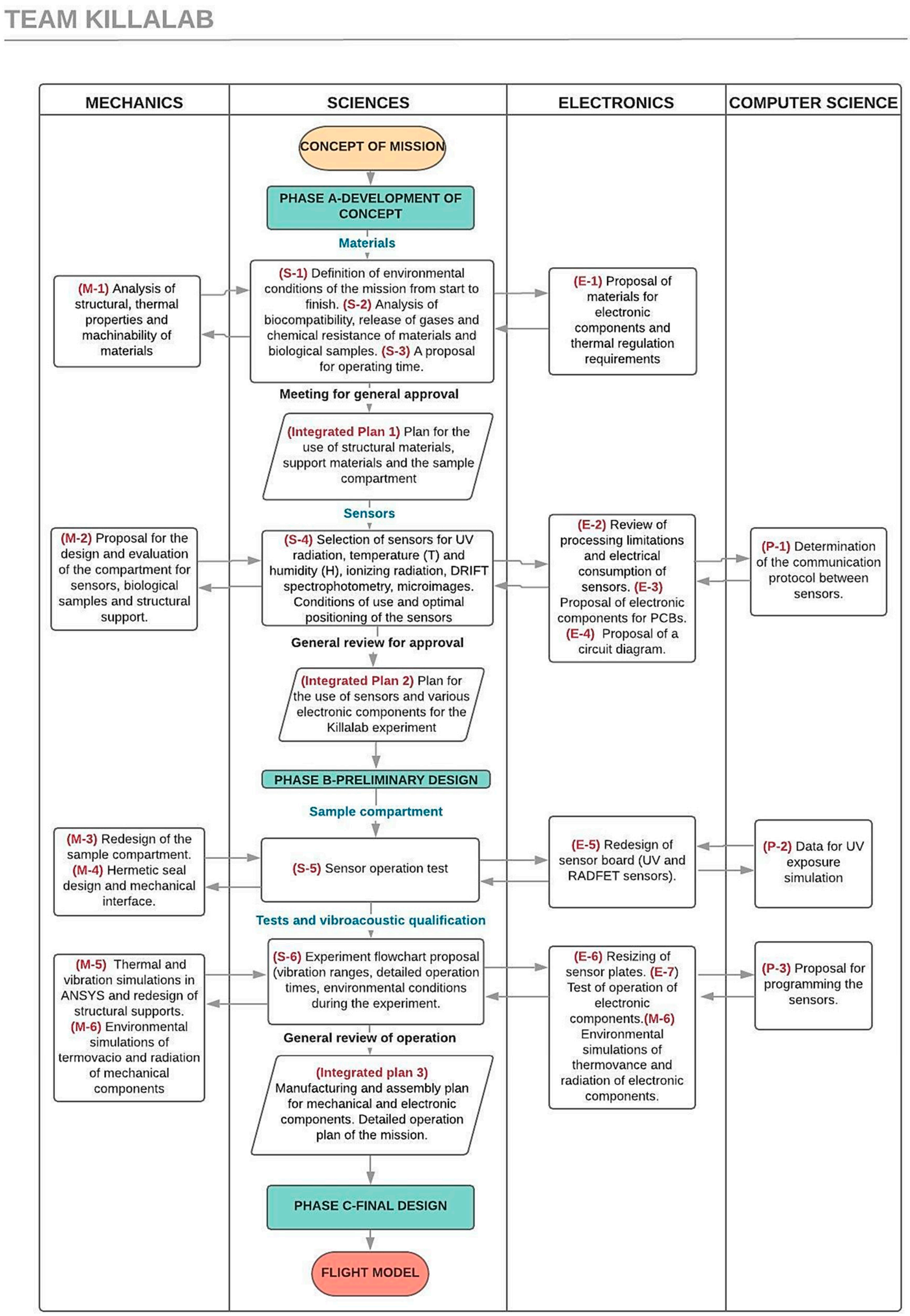

Figure 2. Tasks of team Killalab members from the development of the concept to the final design of the payload (minilaboratory).

5.3. Interdisciplinary Interaction within Team Killalab

Interdisciplinarity was represented within Team Killalab as a result of interactions between the disciplines of biology, chemistry, physics, mechanical engineering, electrical engineering, and computer science. In this representation (Figure 3), the disciplines are denoted with yellow circles and black letters. Astrobiology was included as one more because some of the team members already had a background in astrobiology research. The subject categories are in pink and represent the integration between the disciplines. These subject categories are biochemistry, microbiology, material science, robotics, programming, microelectronics, biophysics, and astrophysics. The subject categories in light blue resulted from a more profound exchange of knowledge, and this had immediate applications for the specific objectives.

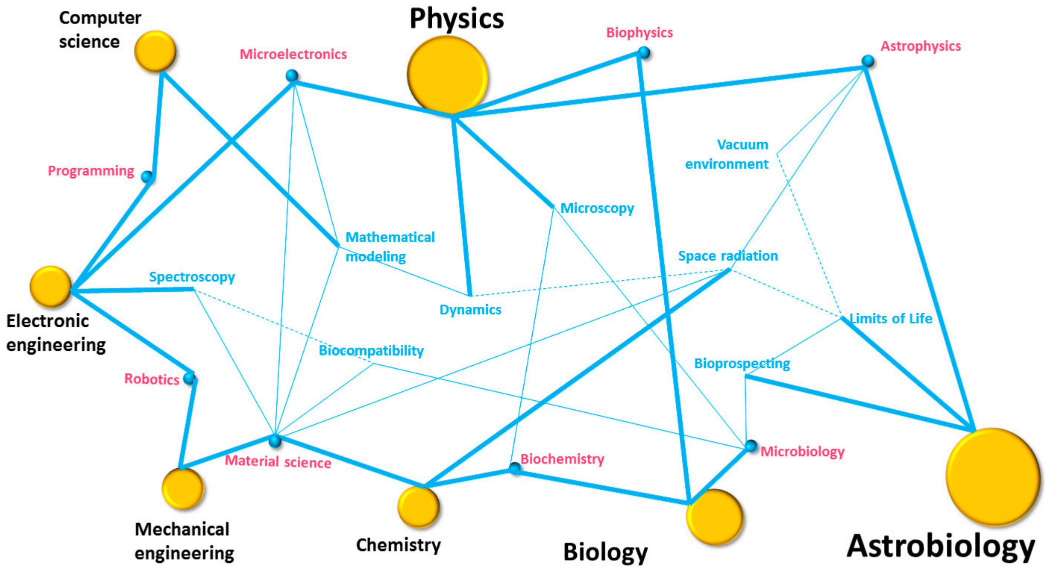

Figure 3. Team Killalab interdisciplinarity representation using subject categories as a result of interactions.

An explanation for the interdisciplinarity obtained within the team is the astrobiology research objective, which needed several disciplines to direct tasks toward a common goal. However, orchestrated combinations of interpersonal relationships and the participation of a PI to facilitate communication between members were also needed.

6. Conclusions

Astrobiology, which by its nature needs several disciplines, facilitated the formation of the Killalab interdisciplinary team, which focused on solving how the biofilms of microorganisms are affected by space conditions.

The use of subject categories as a boundary discipline helped to identify the communication and interaction between the disciplines' team members in the framework of this qualitative research.

The conformation characteristics of teams, such as communication through meetings to resolve knowledge gaps between disciplines, respect between team members, and an order to establish specific objectives and tasks for each discipline, can help improve the implementation and effectiveness of interdisciplinary research or educational programs.

7. Patents

Some authors of the present study have a patent at the National Institute for the Defense of Competition and Protection of Property in Peru, whose title is "Minilaboratory to assess microbial survival", file number 002091-2017/DIN.

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