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H. Inter – and Transdisciplinarity in Science and Technology

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Analysis on disciplines integration challenges for conducting research projects in biotechnologies

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Abstract. Developing and implementing research projects in biotechnologies is possible only by integrating scientific knowledge provided by specialists from various fundamental scientific fields, amongst which chemistry and chemical engineering, biology, agronomy, environmental engineering, energy, economics and social sciences. Inter- and transdisciplinary approach of research projects involves interactions between technical and non-technical disciplines, but also between the members of the research group; often, integrating disciplines is a very challenging task, which requires the collective effort of the project manager and team members. Finding a common language for effective communication within the group and between project partners, adaptability to exploring new knowledge, bridging interactions between research subgroups are just some of the required skills of project team members. This paper aims to identify and analyse the key elements that can guarantee a successful project in a biotechnological field, using both the theoretical approach and the author's own expertise in conducting and coordinating research and development projects.

Keywords: inter- and transdisciplinarity, biotechnologies, research projects, teamwork.

1. Introduction

According to OECD (Organisation for Economic Co-operation and Development) definition, biotechnology is defined as „the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for the production of knowledge, goods and services” [1]. In other words, biotechnology is the branch of applied science that uses living organisms and their derivatives to produce useful products, processes and services in industrial, agricultural, medical, energy and environmental sectors.

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Some biotechnological processes have been known and applied for a long time (for example brewing has taken place since around the 6th millennium BC), but the term biotechnology was first introduced in 1919 by the Hungarian agricultural engineer Károly Ereky in his book Biotechnologie der Fleisch-, Fett- und Milcherzeugung im landwirtschaftlichen Grossbetriebe (Biotechnology of Meat, Fat and Milk Production in an Agricultural Large-Scale Farm). Biotechnology has progressed, developed, and evolved over time, having a rapid evolution in science and technology and generating massive investments, especially in the last few decades. Intervening in the machinery of life, biotechnologies have aroused not only research enthusiasm, but also some social oppositions and dilemmas regarding the ethics of human actions in the nature of biochemical processes, with unfamiliar risks [2]. In the context of these dilemmas, the field of biotechnology faces real challenges in governance, in contemporary policies and strategies regarding the provision of funds for research and investments [2, 3].

Biotechnology and bioeconomy are interrelated but the relations between them are not clearly established [4]. According to the EU Communication, bioeconomy is an economic branch those objectives are channelled to five main directions: Ensuring food security; Managing natural resources sustainably; Reducing dependence on non-renewable resources; Mitigating and adapting to climate change; Creating jobs and maintaining European competitiveness [5]. Therefore, bioeconomy is expected to produce food, chemicals, materials and energy. Bioeconomy involves the use of advanced knowledge of genetics and cellular mechanisms for the development of new processes and products. In this approach, it can be considered that the bioeconomy is a subsector of biotechnology. On the other hand, the bioeconomy aims at the sustainable processing of biomass not only for food manufacturing, but also non-food products (chemicals, biofuels, etc.). In the latter case, the use of new scientific and technological knowledge is secondary.

Regardless of the more technical-scientific or socio-political approach of the two notions, it is obvious that what defines them categorically is the interdisciplinary and multidisciplinary nature. Education in biotechnology requires learning of multiple disciplines amongst which: biology, chemistry, biochemistry, physics, environmental engineering, electrical and computer engineering, mechanics and mechatronics engineering, bioinformatics, medicine and genetics, pharmacology, agronomy, ecology, economics and social sciences.

Although most biotechnology markets are in the field of health and food safety, in recent years industrial and environmental biotechnologies have become an important research and development direction, urged by non-fossil energy needs and environmental protection policies.

This paper is focused on evaluating concrete challenges encountered in carrying out research and development projects in the field of energy and environmental biotechnology, involving specialized work teams in various technical and non-technical disciplines. Also, the communication and collaboration skills within the projects work groups are briefly analysed based on two projects taken as relevant case studies.

2. Materials and methods

In order to identify the challenges of disciplines integration for the development and completion of research and development projects in the field of biotechnologies, a documentary research on biotechnologies and bioeconomy was carried out for a start. Literature screening aimed at clarifying the definition of the two notions bioeconomy / biotechnology, the common elements and differences between them, the technical and socio-political approaches. For this purpose, reports issued by the European Commission and the OECD, official communicates and development strategies, working papers, as well as scientific articles have been used. Desk research for collecting relevant papers and reports was conducted through Google Scholar and Science Direct, using keywords such as “bioeconomy”, “bioeconomy AND strategy”, ”bioeconomy AND biotechnology”, “biotechnology AND interdiscpilinary”, ”interdisciplinary AND challenges”, ”bio-based industries AND sustainability”, etc. The official sites of the European Commission, Organisation for Economic Co-operation and Development, Romanian Government – Ministry of Research, Innovation and Digitalization were explored. In the same way of theoretical investigation, desk research on inter- and transdisciplinarity in research was conducted, including ways of efficient knowledge integration, communication and interaction between team members, disciplines integration challenges. This research particularly involved the exploration of scientific articles and reports in the field of social sciences and communication.

For assessing the inter- and transdisciplinarity of the research projects in the area of biotechnologies and to analyse the challenges in carrying out the tasks according to the committed activities plans, two national projects from the Bioeconomy, respectively Energy, Environment and Climate Change research domains were selected as relevant case studies. The first state-funded project used as a case study was BIOALG (PN-III-P2-2.1-PED-2016-0068, grant number 170PED/2017) that ran from August 2017 to December 2018 and the consortium consisted of two national institutes: ICPE-CA Bucharest and INCDDD Tulcea, Romania. The second state-funded project used for this analysis was a complex project, ABC-Energy (AlgalBiogasConcept Energy, PN-III-P1-1.2-PCCDI-2017-0541) that ran from February 2018 to May 2021 and consisted of four component projects, involving three research institutes and three universities.

3. Results and discussions

3.1 The relationship between biotechnology and the bioeconomy

The precise definition and delimitation of the two notions - biotechnology and bioeconomy - is quite difficult to accomplish, considering that the terms can be seen from different scientific and socio-economic directions (scientists, respectively governmental and non-governmental institutions, companies operating in various sectors). In the Bioeconomy Strategy issued in 2018, the European

Commission defined the bioeconomy as it „covers all sectors and systems that rely on biological resources (animals, plants, micro-organisms and derived biomass, including organic waste), their functions and principles. It includes and interlinks: land and marine ecosystems and the services they provide; all primary production sectors that use and produce biological resources (agriculture, forestry, fisheries, and aquaculture); and all economic and industrial sectors that use biological resources and processes to produce food, feed, bio-based products, energy, and services" [6]. According to this comprehensive definition, biotechnologies are subordinated to the bioeconomy, being responsible for both the development of processes and products based on biomass, but also for biomass processing technologies to biofuels and by-products (including use of residues and wastes), as well as environmental remediation techniques. The image in Figure 1 shows the relationship between biotechnology and the bioeconomy within the concept of circular economy.

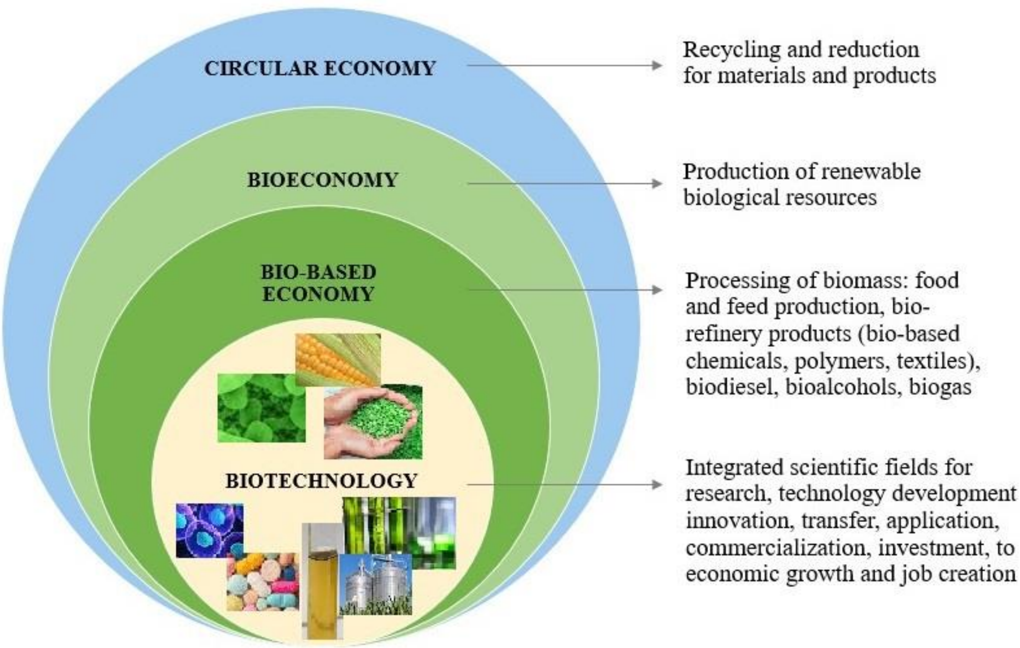

Fig. 1 Biotechnologies within the bioeconomy and circular economy concepts

While biotechnology is an inter- and transdisciplinary field focused on the application of science and technology on biological matter, the bioeconomy is more than an economic sector; it is integrated into day to day life, such as digitization [7, 8].

According to Bugge et al., within the bioeconomy three ideal type visions can be distinguished, that should not be considered completely distinct from each other: A biotechnology vision, focused on biotechnology research, application and commercialization of bio-based technologies in various sectors; A bioresources vision, focused on biological raw materials developing and conversion for agriculture, marine, forestry and bioenergy sectors, establishing new value chains; A bio-ecology vision, focused on ecological processes to optimize the energy and nutrients use, promote biodiversity and avoid environment degradation. The first two visions are significantly influenced by a technical approach [9]. Although biotechnologies have been known and used for thousands of years, their integration into a broader concept of the bioeconomy is a new approach, led by societal challenges such as climate change, demographic growth, food and energy security, disease prevention and treatment, pollution control.

3.2 Inter- and transdisciplinarity of biotechnologies

While interdisciplinary research is based on active interaction tools across disciplines (data, methods, concepts, and theories in order to create a holistic view or common understanding of a complex issue, question, or problem) [10], transdisciplinary research is used for research in which not only different scientific disciplines are involved but also a wide range of stakeholders in the society (citizens, community organizations, NGOs, private companies, etc.) [11, 12].

Biotechnologies and the bioeconomy have an inter-sectorial and interdisciplinary nature, using the science and technnology of multiple disciplines, like biology, chemistry, physics, informatics, engineering, genetics, mathematics, statistics, economics as well as political sciences; it is not possible to make an exact delimitation of the interpenetration of knowledge between these disciplines. The image in Figure 2 shows the disciplines that provide the necessary knowledge in the context of biotechnologies.

Biotechnologies have evolved in thousands years from the ancient ones (biotechnologies for basic needs such as food preparation or preservation, also genetic modification to improve plants and animals by selective breeding), to the classic ones (fermentation to make bread, curd, yogurt, cheese, beer, wine, without completely knowing the science behind these processes), and modern biotechnologies (based on the manipulation and control of microorganisms for the creation of new products in various sectors as medical, agriculture, food, environments bioremediation, biofuels production). It is obvious that the study paths in biotechnologies are unlimited in searching new applications with the main benefits outlined in the future [11]. However, there are currently some concerns and controversies about how much overdeveloped biotechnology should be so as not to negatively affect the environment and the health of the population [11, 12].

A biotechnologist cannot achieve the objectives of innovation, development and control of biotechnological processes without using knowledge from chemistry, engineering, biology, computer science and many others. This requires a reorganization of schools and universities curricula, given the growing need for a more adequate understanding of the phenomena that lie in the interdisciplinary area. For example, in bioindustries involving fermentation processes and products, the traditional education for chemical engineers and industrial plant designers has not normally included biological processes.

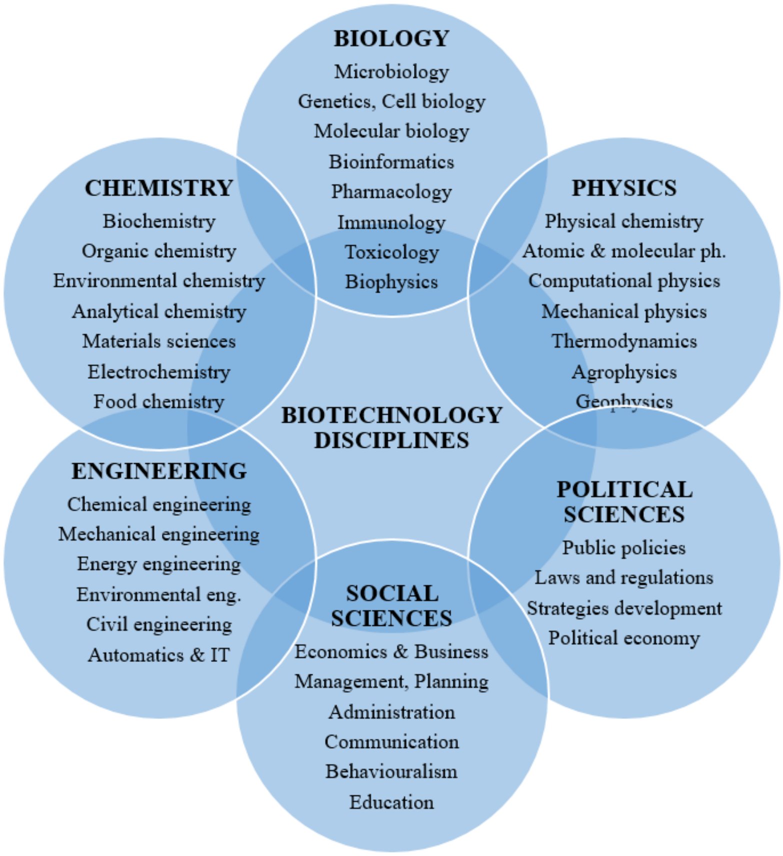

Fig. 2 Interrelations between biotechnology disciplines

The nature of the materials required, the reactor vessels (bioreactors) and the operating conditions are so different that complete retraining is required [13]. Skilled specialists in biotechnologies should be trained starting from the premise that this is rather a field of the 21st century, which has been continuously developing and scaling-up based on the knowledge acquired in the 20th century (chemistry, biology, biochemistry, physics, engineering, economy etc.). Innovations in biotechnology do not necessarily materialize with new products or processes, but rather with the improvement of organisms involved in producing existing products, respectively in optimizing technological processes. It is therefore essential to develop inter- and transdisciplinary biotechnological knowledge and use a common language among specialists to bridge the gap in effective communication.

3.3. Challenges of integrating disciplines in research and development projects

Inter- and transdisciplinary research projects have become increasingly important in the research landscape in recent years, but they face real challenges of both practical and institutional nature [14]. In general terms, the practical challenges include the difficulties of organizing meetings, developing a common language and knowledge, and understanding the task at hand [15]. Institutional challenges are mainly related to the organization of departments in well-defined fields (chemical, mechanical, biological, financial-accounting, marketing, etc.), issues of personnel recruitment, performances evaluation and motivation tools so that high quality interdisciplinary research is supported and stimulated. For example, in an academic institution (university, research institute) one of the perceived barriers to interdisciplinary projects is that it requires faculty or department members to temporarily or permanently leave their disciplinary and thus loss of professional identity. Moreover, researchers have a large investment in themselves and are likely reluctant to give up the position of influence and professional status they have attained as a result of their disciplinary achievements in the context of institutional competition among individuals [16]. The following main challenges can be emphasized from the selected literature [11, 17, 18, 19, 20]:

- Start-up phase and implicitly the implementation time of interdisciplinary projects is longer than for disciplinary projects, because it takes longer to explore more dimensions of the problem to be solved until the boundaries are framed and the optimal dimensions are outlined;
- Project team members have different knowledge and different levels and angles of terminology and phenomena understanding, therefore there are important difficulties in communicating and understanding the project objectives, the possibilities to achieve the assumed objectives, the limitations, advantages and disadvantages. As a consequence, there are difficulties in drawing up a joint plan of activities, commonly agreed within the team;
- Interdisciplinary work demands for certain capacities and capabilities of the project leader and team members, such as flexibility, receptivity and sensitivity to others, as well as skills in reacting to receiving new information, ability to ask relevant additional information, ability to clarify, compare and synthesize. Creativity, great openness and willingness to learn from other disciplines are required;
- Low frequency of interaction between team members is an obstacle in bridging organizational boundaries. More and diverse interactions may result in better mutual understanding and may facilitate inter- and transdisciplinary work;
- The team members feel low or no personal motivation and do not understand to have a project commitment under the joint effort for achieving the project objectives.

Figure 3 shows the disciplines profile of the work teams and interdisciplinary issues inspection for two research projects coordinated by the author over the past four years.

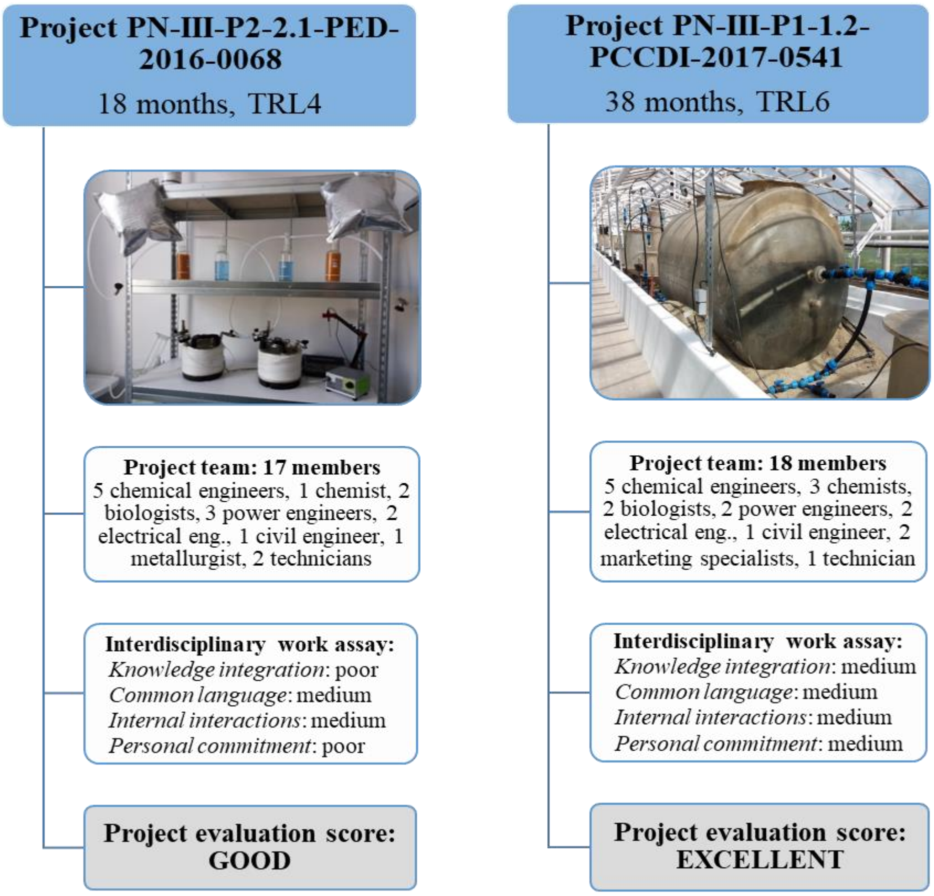

Fig. 3 Interdisciplinary research projects survey: Case studies [21, 22]

In both cases, knowledge integration was unsatisfactory and created some problems in fully understanding the objectives of the project. It was noticed rather low individual involvement and initiatives in identifying technical solutions, methods of analysis, biomass substrates selection, acquisition of appropriate equipment, results dissemination etc. The main cause for these difficulties was the lack of essential knowledge in fields other than those acquired in universities and low openness and willingness to learn from other disciplines. Knowledge integration was slightly better during the second project, partly as a result of the scientific experience gained in the previous project, but also due to the longer time scheduled for the project start-up. In both projects, team members showed medium opening for sharing a common language and mutual understanding. During the projects meetings, it was observed a reluctance of members to participate in discussions, to ask questions and propose solutions. Such behavior translates into a vague understanding of the terminology, more precisely by lack of a common language. Another important challenge was bridging internal interactions. These interactions were more frequent between members of the same professional category and age category, but less inter- and transdisciplinary interactions for the benefit of the projects. Personal commitment was low in the first project and slightly improved in the second project while the individual motivation in achieving the objectives was generally low, as well as the individual interest in participating with own contribution to the dissemination activities. Despite these challenges, management and implementation teams' joint efforts have led to both projects being successfully completed, in line with the objectives set.

4. Conclusions

Biotechnologies are an economic and research field of inter- and transdisciplinary nature, which integrates many technical and non-technical disciplines to solve problems in medicine, agriculture, food and bioenergy industries, environmental protection etc. Disciplines integration significantly depends on interactions and individual skills of the team members. Practical studies reinforce the statement that inter- and transdisciplinarity are a must in current and future projects in biotechnologies but appropriate management of existing challenges is the key to develop and implement successful projects.

References

[1] European Commission, Eurostat publications, *Glossary: Biotechnology*, 2018, ISSN 2443-8219, Available at: https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Glossary:Biotechnology.

[2] Hilgartner S., *Biotechnology*, International Encyclopedia of the Social & Behavioral Sciences, 2001, p. 1235, doi: 10.1016/B0-08-043076-7/03147-8.

[3] Mateescu C., Dima AD., *Critical analysis of key barriers and challenges to the growth of the biogas sector: a case study for Romania*, Biomass Conversion and Biorefinery, **10**, 2020, p. 13399.

[4] Befort N., *Biotechnology vs. The bioeconomy*, Working paper NEOMA Business School, 2019.

[5] European Commission, *Innovating for Sustainable Growth: A Bioeconomy for Europe* (Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions No. SWD (2012) 11 final), 2012.

[6] European Commission, *A Sustainable Bioeconomy for Europe: Strengthening the Connection between Economy, Society and the Environment. Updated Bioeconomy Strategy,* 2018. Available at: https://eur-lex.europa.eu/legalcontent/EN/TXT/?uri=CELEX%3A52018DC0673.

[7] Wesseler J., von Braun J., *Measuring the Bioeconomy: Economics and Policies,* Annu. Rev. Resour. Econ, **9**, 2017, p. 275–298.

[8] Kardung M., Cingiz K., Costenoble O., Delahaye R., Heijman W., Lovri´c M. et al. *Development of the Circular Bioeconomy: Drivers and Indicators*, Sustainability, **13**, 2021, p 413.

[9] Bugge M.M., Hansen T., Klitkou A., *What is the bioeconomy? A review of the literature*, Sustainablitily **8**, 2016, p. 691.

[10] Wagner C.S., Roessner J.D., Bobb K., Klein J.T., Boyack K.W. et al., *Approaches to understanding and measuring interdisciplinary scientific research (IDR): A review of the literature*, Journal of Informetrics, **165**, 2011, p. 14-26.

[11] Edelenbos J., Bressers N., Vandenbussche L., *A project's evolution of interdisciplinary collaboration*, Science and Public Policy, **44,** 4, 2017, p. 451-463.

[12] Smith J. E., *Biotechmnology: Fifth Edition*, Chapter 1, Ed. Cambridge University Press, 2009, 978-0-521-88494-5, Available at: www.cambridge.org

[13] Dr. B. Lal Institute of Biotechnology, *Biotechnology: An Interdisciplinary Approach*, Available at: https://www.blalbiotech.com/blog/author/blalbiotech/
[14] Domino S.E, Smith Y.R, Johnson T.R., *Opportunities and challenges of interdisciplinary research career development: implementation of a women's health research training program*, J Womens Health (Larchmt), **16,** 2, 2007, p. 256-261. doi:10.1089/jwh.2006.0129
[15] Pfirman S.L, Collins J.P., Lowes S., Michaels A.F., *Collaborative efforts: Promoting interdisciplinary scholars*, Chronicle Higher Education, **51**, 2005, B.15.
[16] Lattiuca L.R., *Creating Interdisciplinarity: Interdisciplinary Research and Teaching among College and University Faculty*, Nashville, TN: Vanderbilt University Press, 2001, p. 37.
[17] Podesta G.P., Natenzon C.E., Hidalgo C., Toranzo F.R., *Interdisciplinary production of knowledge with participation of stakeholders: A case study of a collaborative project on climate variability, human decisions and agricultural ecosystems in the Argentine Pampas*, Environ. Sci.and Policy, **26**, 2013, p. 40-48.
[18] Reagans R., McEvily B., *Network structure and knowledge transfer: The effects of cohesion and range*. Administrative Science Quarterly, **48**, 2, 2003, pp. 240-267.
[19] Van den Bossche P., Gijselaers W.H., Segers M., Kirschner P.A., *Social and cognitive factors driving teamwork in collaborative learning environments*, Small Group Research, **37**, 2, 2006, p. 490-521.
[20] Woinaroschy A., *Personal considerations about creativity and artificial intelligence*, Journal of Engineering Sciences and Innovation, **5**, 1, 2020, p. 63-68.
[21] Project PN-III-P2-2.1-PED-2016-0068, *Development and validation of reliable solutions to produce biogas from algal biomass in the Danube Delta Biosphere Reserve*, Grant 170PED/2017
[22] Project PN-III-P1-1.2-PCCDI-2017-0541, *Enhancing the energy efficiency of the biogas plants by developing an integrated system: biogas-microalgae-biofuels, within the biorafining concept,* Grant 32PCCDI/2018.