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STEAM+ H CONTRIBUTES TO THE SYNERGY OF SCIENCE TO GENERATE SUSTAINABLE SOLUTIONS

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ABSTRACT:
The synergy of the sciences through the STEAM+ H methodology provides an opportunity for integrating knowledge from various disciplines to generate comprehensive proposals with a human sense, increasing the probability of success due to a systemic approach that holistically includes the elements of a system. In this complex world, with urgent challenges to be solved, it is necessary to utilize multidisciplinary approaches to generate innovative solutions that contribute to the Sustainable Development Goals (SDGs). Sustainability is an urgent and pressing issue that demands substantive actions in all spheres, including social, ecological, and economic. The inclusion of the Humanities is required to enrich approaches, as most situations involve human-related aspects. The STEAM+H experiences also manage to develop in the members of the project critical thinking, socio-emotional skills, application of Ethics in addition to the valuable STEAM skills related to technological aspects; The results are very successful and have an impact on broad sectors through efficient and successful solutions in various aspects, not only contributing to the global problems of the 2030 Agenda.

KEYWORDS: Sustainability, Synergy, Innovation, Interdisciplinarity, Problem Solving.

1) INTRODUCTION:

In the face of the complex challenges facing the contemporary world—such as social, environmental, and economic crises—the interdisciplinary integration represented by the STEAM+H (Science, Technology, Engineering, Arts, Mathematics, and Humanities) approach is presented as a viable alternative to generate sustainable solutions. The synergy of the sciences enables us to develop comprehensive proposals that address the increasing complexity of current problems.

Sustainability, according to Foladori (2023), "is understood as the ability to maintain ecological, social, and economic balances over time, adapting to global changes and challenges." Along the same lines, the UN (2023) defines sustainable development as "the satisfaction of the needs of the present without compromising the ability of future generations to meet their own needs". However, in an era marked by accelerated technological advancement and intensive consumption patterns, maintaining these balances becomes increasingly tricky.

Martínez (2020) highlights that "sustainability can be understood as the balance between the demands of modern society and the regenerative capacity of ecosystems". The high consumption of resources, as well as the degradation of ecosystems for the sake of economic profit, have made sustainability one of the most significant challenges of the 21st century. Faced with this panorama, all sectors of society must be actively involved. As Sánchez (2020) points out, "sustainability is not only an objective, but a dynamic process that involves the active participation of all sectors of society".

This collaborative vision encompasses a wide range of stakeholders, including international organizations, governments, industries, and local communities. Guerrero (2019) stresses that "the concept of sustainability has expanded to include the importance of global governance and international cooperation", which is essential to achieve real impact on a global scale.

Sustainable challenges are multidimensional and encompass numerous variables that make them complex to address. In this context, the synergy between different disciplines becomes key. From the perspective of complexity science, the integration of knowledge is essential for generating innovative solutions. Curtin (2020) argues that "synergy is fundamental in research projects that combine multiple disciplines to address complex problems".

The use of emerging technologies, digital tools, and computational models has been a response to the increasing complexity of current problems. As Chundong & Yibo (2020) state, "the analysis of the synergy between different types of policies and tools is key to effectiveness in science and technology policymaking." S. Gaitán (2019) reinforces this idea by pointing out that "collaboration between different scientific actors is crucial for progress and sustainability in various fields".

Finally, the interconnection between science, technology, and society is fertile ground for progress, but also for the emergence of new challenges. As various studies conducted by university students have discussed, mutual understanding and collaboration among these three pillars are essential to building a balanced, fair, and resilient future.

2) METHODS AND METHODOLOGY:

The STEAM (Science, Technology, Engineering, Arts, and Mathematics) methodology represents an educational innovation aimed at developing talent in multiple dimensions: cognitive, technological, scientific, creative, and socio-emotional. It is not limited to the construction of knowledge, but encourages the development of soft skills, work competencies, and critical thinking through experiential and transdisciplinary learning.

From a qualitative research perspective, the grounded theory approach allows us to identify emerging patterns, dynamics, and meanings in the STEAM educational process. This methodology not only structures learning from the disciplines but also begins with the direct experience of students, generating knowledge through interaction in specific social contexts. The synergy generated in collaborative teams provides insights to identify good practices, educational innovations, and emerging forms of learning.

The STEAM model aims to address the shortage of professionals in STEM fields, integrating art as a catalyst for creativity and innovation in the so-called Fourth Industrial Revolution. Its purpose is to train professionals capable of creating innovative, interdisciplinary, and sustainable solutions, while also encouraging interest in scientific disciplines among students from basic, secondary, and higher education. Learning is closely linked to the Sustainable Development Goals defined by the UN.

According to various authors, this methodology promotes the acquisition of key competencies, including research, diagnosis, and proposal of solutions, as well as collaborative work, team management, and conflict resolution. It also strengthens skills such as emotional self-regulation, leadership, assertive communication, and decision-making. All this in learning contexts that simulate real challenges and demand critical, creative, and reflective thinking.

STEAM integrates multiple forms of knowledge, enabling the solution of complex problems. Technology and programming are understood not only as tools, but also as part of a technological education tailored to today's needs. The natural sciences and engineering provide technical knowledge, while mathematics serves as a structural foundation in the development of models and simulations. Art brings aesthetics, harmony, and creativity, which humanizes the technical process and encourages innovation in products and solutions.

The STEAM approach aligns with the 17 Sustainable Development Goals proposed by the UN, utilizing strategies such as Project-Based Learning (PBL). This strategy enables the addressing of complex problems, the design of innovative solutions, and the generation of positive impacts from the classroom to society. PBL provides structured steps for research and supports the integration of knowledge that characterizes STEAM transdisciplinary approaches.

Therefore, STEAM is not only a methodology but a transformative paradigm that redefines the role of the student as an active agent of knowledge and social change. It is a training commitment based on collaboration, open innovation, and sustainable development. The synergy between science, technology, art, and society thus becomes the catalyst for transformative solutions with local and global impact.

Figure 1: Sustainable Development Goals Source : (ONU, 2015)

STEAM is a methodology that favors sustainable, innovative solutions through the construction of new knowledge, as well as the development of multiple skills. STEAM to the icorpora PBL Project-based learning are active strategies that seek the integration of the knowledge needed to generate a solution from a project, as mentioned The Project-based Methodology: is a central strategy in STEAM education, since through it the key concepts of the associated disciplines are valued within the framework of a problematizing situation. PBL provides the orderly steps to follow within an investigation, which supports the vast knowledge gathered in the interdisciplinary field of STEAM. Fig. 2 is shown below. STEAM-ABP methodology. (Castro-Campos, 2023)

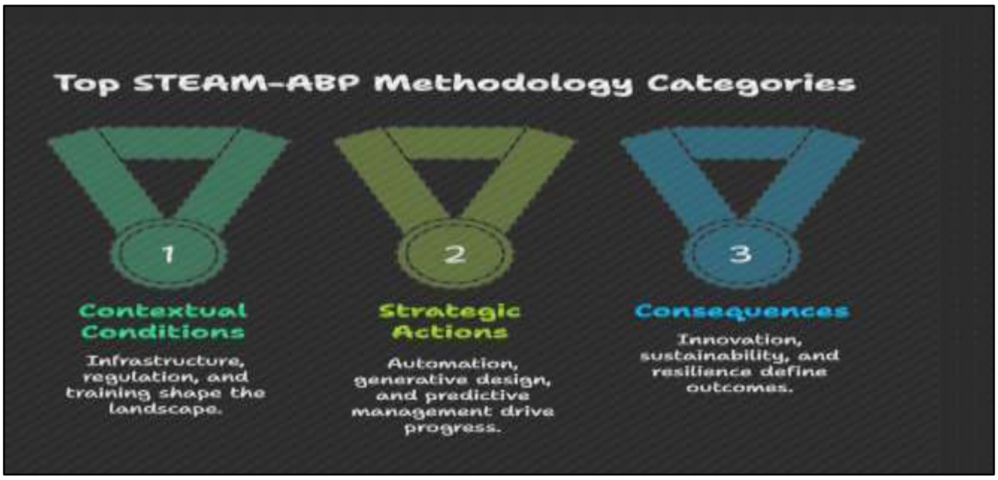

Figure 2 STEAM-ABP Methodology Source: (Yarzábal Coronel, Ávila Ávila, Álvarez Cedillo, & Núñez Navarrete, 2022)

The application of K-Means in our study arises after the formation of teams. The data was reviewed and analyzed, and this is what happened after observing the database, which consisted of 25 measurement points along the river, had an age of more than 10 years, and included 75 measurement parameters. One proposal would be to use Artificial Intelligence (AI) to analyze the data in the vast database. After a preliminary analysis of the data and subsequent cleaning, it was decided to utilize a machine learning algorithm. The application of K-Means is a subset of Artificial Intelligence (AI). The function of the K-Means application is to group the data into groups (clusters) based on similarities, which helps to find patterns and understand how the different sampling points behave depending on the parameters of the Santiago River located in Guadalajara.
The goal of K-Means is to minimize the sum of the squared distances between the data points and the centroid of the assigned cluster. The algorithm employs an iterative approach to adjust the cluster centroids and minimize the total error function. Formally, the goal is to reduce the following function:

$$J = \sum_{i=1}^{k} \sum_{x_i \epsilon C_1} \left\| x_j - \mu_i \right\|^2$$

Where:
• J is the cost (or inertia) function,
• K is the number of clusters,
• Ci represents the set of data points assigned to cluster i,
• μi is the centroid of cluster i,
• xj is a data point.
The K-Means algorithm follows a series of iterative steps until the clusters stabilize or a maximum number of iterations is reached. The main steps are:
1. Initialization:
o A K number of clusters is chosen.
o K random points are selected as the initial centroids of the clusters.
2. Cluster Assignment:
Each data point is assigned to the cluster whose centroid is closest, using the Euclidean distance as a proximity criterion. The Euclidean distance between two points x and y in n-dimensional space is given by:

$$d(x, y) = \sqrt{\sum_{i=1}^{n} (x_i - y_i)^2}$$

Once all points are assigned to their respective clusters, the centroids are recalculated. The new centroid of each cluster is the arithmetic mean of all observations within the cluster:

$$\mu_i = \frac{1}{|C_i|} \sum_{x_j \epsilon C_i} x_j$$

Steps 2 and 3 are repeated until the point assignments no longer change (convergence) or a maximum number of iterations is reached. Convergence occurs when the cost function no longer decreases significantly from one iteration to the next.
A critical aspect of the algorithm is the choice of the number of clusters K. There is no exact mathematical method to determine K, but there are several empirical methods, such as:

1. Elbow Method: It consists of running the algorithm for different values of K and calculating the sum of the squared distances within the clusters (inertia). The optimal value of K is chosen where the decrease in inertia begins to decrease abruptly, forming an "elbow" in the graph.
2. Silhouette Score: Evaluates the quality of clusters based on how close points within the same cluster are compared to points in other clusters.

It is part of the STEAM Methodology that innovations are rigorous contributions to solving the SDGs, as well as harnessing the talents of young people to form collaborative work teams.
Some examples of synergy of the sciences are explained below.
STEAM+H is an evolution of the STEAM (Science, Technology, Engineering, Arts, and Mathematics) educational approach that also incorporates the Humanities. The application of STEAM+H in artificial intelligence and data analysis projects with machine learning can be profoundly transformative.
In an urban environment like Mexico City, an AI system could be developed that analyzes environmental data, mobility patterns, and emotions expressed on social networks to improve quality of life. Using machine learning, the system would learn from millions of human interactions, pollution heat maps, noise and population density reports, as well as from literature, urban art, and site history. This holistic approach enables not only the prediction of phenomena or the automation of services, but also the generation of culturally sensitive interventions. A smart city that responds to the emotional changes of its citizens, adapting its lighting, green spaces, and cultural programming in real-time. AI, trained with complex data and human narratives, becomes a mediator between technology and well-being. Look at Figure 3.

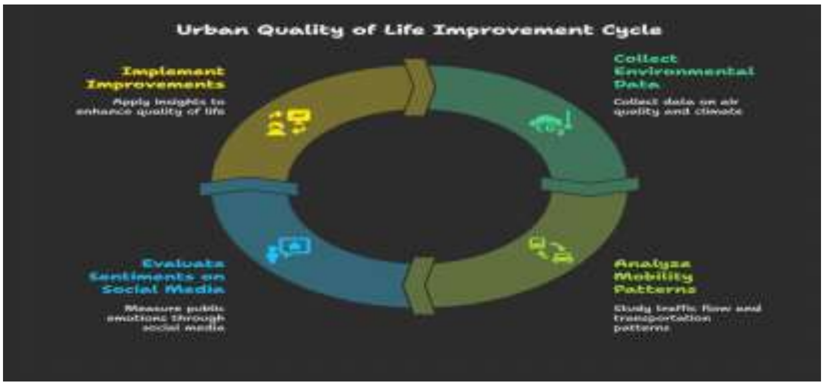

Figure 3. In an urban environment like Mexico City, an AI system could be developed to analyze environmental data, mobility patterns, and emotions expressed on social media, thereby improving the quality of life. Using machine learning. TEAM-ABP Methodology Source: (Yarzábal Coronel, Ávila Ávila, Álvarez Cedillo, & Núñez Navarrete, 2022)

It is also possible to visualize an interactive map where areas with the most significant social stress are illuminated in warm, soft tones, while places of high cultural dynamism stand out in vibrant colors. This type of visualization, supported by art and design, makes technical information accessible, allowing anyone—regardless of background—to participate in data-driven decisions. Look at Figure 4.

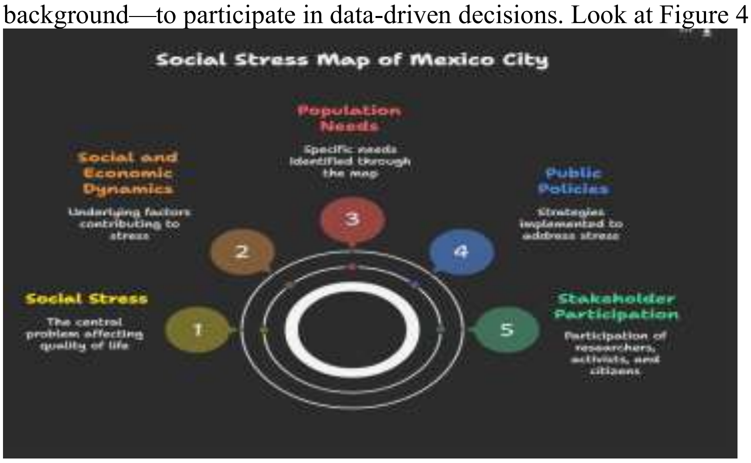

Figure 3. In an urban environment like Mexico City, an AI system could be developed to analyze environmental data, mobility patterns, and emotions expressed on social media, thereby improving the quality of life. Using machine learning. Source: (Yarzábal Coronel, Ávila Ávila, Álvarez Cedillo, & Núñez Navarrete, 2022)

3) RESULTS:

The results generated by the Artificial Intelligence project at the Hydro-Hackathon have profound implications for the community, both technically, socially, and culturally.

By identifying critical areas of the Santiago River through intelligent grouping, a focused response is enabled that can improve water quality in specific areas with greater efficiency and reduced resource expenditure. For nearby communities, this translates directly into an improvement in public health, a reduction in diseases associated with contaminated water, and a revaluation of their natural environments.

In addition, by democratizing access to data and visualizing it clearly, the project empowers citizens: they are no longer simple observers, but informed actors capable of demanding action, participating in action plans, and adopting responsible practices. The communication of the findings through graphic resources or humanized narratives also strengthens the emotional bond with the river, fostering a sense of belonging and shared responsibility.

In the long term, this integration of AI, environmental data, and STEAM+H education forms a foundation for creating more inclusive and effective public policies. A collaboration model is promoted that integrates science, technology, and humanities to regenerate ecosystems and enhance community life, recognizing the value of both technical knowledge and local knowledge.

Of course. Here is the expanded text with a detailed explanation of each category included in the table, keeping the style fluid and argumentative without bullets:

Table 1 summarizes the expected results of the Artificial Intelligence project applied to the study of the Santiago River, within the STEAM+H framework. Each category responds to a strategic dimension of technical and social intervention.

Table 1: Expected results of the Artificial Intelligence project applied to the study of the Santiago River, within the STEAM+L framework. Source: Results of this research

Category	Expected results
Identification of critical areas	Intelligent classification of points of high pollution in the Santiago River through clustering algorithms and analysis of environmental patterns.
Resource optimization	Implementation of targeted measures that allow specific areas to be treated more effectively, reducing costs and maximizing positive impact.
Public health	Reduction of diseases related to contaminated water, improving the quality of life in nearby communities.
Environmental revaluation	Reconnection of inhabitants with their natural environment, thanks to visible improvements in the river ecosystem.
Citizen empowerment	Free and understandable access to environmental data that transforms citizens into active agents with the capacity to influence, denounce, and propose.
Participatory communication	Dissemination of findings through visual and humanized narratives that foster emotional engagement and a sense of community belonging.
STEAM+H Education	Interdisciplinary integration that articulates science, technology, and the humanities, strengthening critical thinking and systemic analysis in students and participants.
Public policies	Generation of technical and social inputs for the creation of inclusive regulations based on evidence, local knowledge, and environmental justice principles.
Ecological regeneration	Progressive restoration of degraded habitats through evidence-based interventions and sustainable, community-led practices.

Identifying **hotspots** using intelligent clustering algorithms can reveal patterns of contamination that might otherwise go unnoticed. This methodology not only pinpoints the most affected points but also provides a dynamic understanding of environmental behavior, facilitating timely and targeted interventions.

With this, an **optimization of** both technical and human resources is achieved. By focusing on priority areas, the unnecessary use of treatments, energy, and time is minimized, favoring a more sustainable approach. This targeting transforms environmental management into a more strategic and less reactive process.

In terms of **public health**, the benefits are immediate: by reducing exposure to contaminated water, the incidence of gastrointestinal, dermatological, and respiratory diseases among the population decreases. This has a positive impact on the quality of life and health costs for families and local institutions.

Environmental **revaluation** occurs when communities observe fundamental changes in the ecosystem. The river ceased to be a symbol of abandonment and began to recover its ecological and cultural value. This process strengthens rootedness and stimulates conservation from a deep sense of belonging.

By clearly opening and visualizing the data, the project promotes **citizen empowerment**. People access knowledge of what is happening in their environment, interpret it, and make informed decisions. This transformation democratizes science, placing citizens at the center of socio-environmental action.
The **participatory communication** of the findings, through visual narratives and humanized stories, reinforces the emotional bond between the communities and the river. It is not only about disseminating data, but also about telling stories that mobilize emotions, memories, and collective commitments.
From the **STEAM+H** approach, technical knowledge is articulated with the humanities. This integration promotes the development of educational projects that bridge complex data with human experiences, encouraging students and participants to think beyond isolated disciplines, thereby fostering critical thinking and social creativity.
Ultimately, the knowledge generated serves as the foundation for **more inclusive public policies**. With scientific evidence and citizen participation, environmental regulations can be designed that respect both human rights and ecosystems. This synergy enables the envisioning of new development models that acknowledge local knowledge and promote ecological justice.
The Synergy of Sciences is demonstrated and developed with theSTEAM+ H Methodology. PBL contributed to the order of the projects. The projects were enriched with various sciences such as Chemistry, Mathematics as well as Data Science and the use of AI for the analysis of multiple historical data. The applied STEAM-PBL Synergy resulted in some innovative sustainable solutions that will be explained below.
STEAM+H fulfilled the purpose of designing innovative and sustainable proposals to contribute to Sustainable Development Goal 6 (SDG 6) of Clean Water with the application of AI. This demonstrates the synergy of sciences contributes to the application of STEAM+H for the development of Critical Thinking as well as for generating awareness to improve in the area of Sustainability.

4) DISCUSSION:

The implementation of AI in monitoring the Santiago River demonstrates that technology can be profoundly humanizing when it is oriented towards the common good. Intelligent clustering not only pinpoints problem areas but also bridges the gap between technical knowledge and local experiences. This intertwining favors more sensitive and effective environmental interventions.
At the social level, the opening of data transforms the paradigm of participation: people are no longer passive recipients of policies and become valid and necessary interlocutors in decision-making processes. Culturally, the river ceases to be seen as an alien or utilitarian element and becomes an integral part of the collective identity, a symbol of memory, resistance, and hope.
The STEAM+H approach is not a sum of disciplines, but an ecology of knowledge. In this project, science and art dialogue, technology and ethics converge, creating new narratives of regeneration. A culture of innovation is built that does not exclude but invites us to imagine sustainable futures with multiple voices and perspectives.
STEAM+ H Synergy offers learning opportunities and collaboration across disciplinary fields, providing the opportunity to leverage all kinds of methodologies and knowledge to contribute to the development of sustainable solutions. However, the challenge will be training faculty and research staff to move beyond their expertise and develop methodologies that support the development of their projects.

5) CONCLUSION:

The conclusion of the Artificial Intelligence project applied to the Santiago River, under the STEAM+H approach, highlights a profound transformation in the relationship between technology, environment, and society.
The application of intelligent grouping algorithms has enabled not only the identification of critical areas of contamination but also the design of more efficient and targeted intervention strategies. This technical capacity, when integrated with a participatory and humanized narrative, turns data into tools for citizen empowerment and territorial healing. Communities cease to be spectators and become active protagonists of ecological regeneration.
Open access to environmental information strengthens participation, fosters accountability, and cultivates a new culture of shared responsibility. Beyond the immediate impacts on health and the environment, the project promotes a long-term vision that integrates education, science, the arts, and humanities to envision a fairer and more sustainable future. In this sense, the project is not limited to solving an environmental problem: it proposes a new way of inhabiting knowledge, recognizing the intelligence of data and the wisdom of people. It is a sign that when technology is put at the service of life, it can become a bridge between what we are and what we can still become.
Synergy, STEAM + H, are learning opportunities and collaboration across disciplinary fields, the opportunity to leverage methodologies and knowledge of all kinds to contribute to the development of sustainable solutions. However, the challenge will be training faculty and research staff to move beyond their expertise and develop methodologies that contribute to the development of their projects

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8) Conflict of interest: The authors declare that there is no conflict of interest.

9) REFERENCES

[1]. Castro-Campos, P. (March 16, 2023). Reflections on STEAM education, an alternative for the 21st century. Retrieved from Praxis: https://revistas.unimagdalena.edu.co/index.php/praxis/article/view/3762
[2]. Raynaud, D. (2018). What is technology? Followed by the Epilogue on technoscience. Retrieved from philpapers: https://philpapers.org/rec/RAYQEL
[3]. Amor Bravo, E. (April 04, 2018). From STEM to STEAM: Much more than the interplay of art and science. Retrieved from Educaweb: https://www.educaweb.com/noticia/2018/04/04/stem-steam-mucho-mas-interaccion-arte-ciencia-16384/
[4]. Chundong, G., & Yibo, N. (2020). Research on the synergy of science and technology policy types and policy tools based on policy text analysis. Journal of Physics: Lecture Series, 1774-1790. DOI:DOI:10.1088/1742-6596/1774/1/012006
[5]. Coello Pisco, S. M., Crespo Vaca, T., Hidalgo Crespo, J., & Díaz Jiménez, D. (2018, 01, 05). The STEM model is a didactic methodological resource for building critical scientific knowledge in physics students. Retrieved from Latin-American Journal of Physics Education 12(2), 2306-1 - 2306-8.: https://dialnet.unirioja.es/servlet/articulo?codigo=6556407
[6]. University students. (n.d.). Visions on the synergy of science, technology, and the dynamics of society: fostering relevant learning experiences. Retrieved from https://www.co. (ResearchGate, Ed.)
[7]. Curtin, N. (2020). Between Science and Serendipity: The development of rucaparib/rubraca®: A history of the synergy of cancers. Cancers, 12(3), 564-578. doi:https://doi.org/10.3390/cancers12030564
[8]. F. Ruiz, V., Zapatera, A., Montes, N., & Rosillo, N. (2019, 05, 13). STEAM projects with LEGO Mindstorms for primary education in Spain. Retrieved from the Congress of the Polytechnic University of
[9]. Valencia, INNODOCT 2018: http://ocs.editorial.upv.es/index.php/INNODOCT/INN2018/paper/view/8836
[10]. Foladori, G. (2023). Sustainability in the social sciences. Ecology and Society, 18(2), 134-150.
García Fuentes, O., Martínez Figueira, E. M., & Raposo Rivas, M. (2023, 01, 09). The educational approach STEAM: A Review of the Literature. Retrieved from Revista Computense de Educación. : https://revistas.ucm.es/index.php/RCED/article/view/77261
[11]. González Fernández, M. O., Flores González, Y. A., & Muñoz López, C. (2021). Overview of educational robotics in favor of STEAM learning. Retrieved from Eureka Journal on Science Teaching and Dissemination, vol. 18, no. 2, 2021: https://www.redalyc.org/journal/920/92065360002/92065360002.pdf
[12]. Guerrero, L. &. (2019). Global Governance for Sustainability. International Journal of Sustainable Development, 16(2), 35-50.
[13]. Martínez, R. (2020). Sustainability in times of climate change. International Journal of Ecology, 22(1), 12-
[14]. NSF. (2017). What is STEAM? Steam stem. Washington, U.S.A.: U.S. National Science Foundation Producer, F.N. National Science, Producer.
[15]. UN. (2015). Sustainable-Development-Goals. 2021: UN.UN. (2023). Review of the Brundtland report: 30 years later. Global Sustainable Development, United Nations Organization. 25(1), 10-25.
[16]. Ruiz, F. (2017). Design of STEAM Projects from the Current Primary Education Curriculum Using Problem-Based Learning, Cooperative Learning, Flipped Classroom, and Educational Robotics. Spiral.
[17]. S. Gaitán, M. B. (2019). Initiative of scientific actors to develop sustainable and competitive aquaculture: Colombian Academic Association of Aquaculture-ACCUA. Intropica, 14(2), 90-94. Retrieved from https://revistas.unimagdalena.edu.co/index.php/intropica/article/view/3292
Sánchez, A. (2020). Social participation and sustainability. Journal of Social Sciences, 18(3), 78-94.
[18]. Solórzano, M. (2017). Autonomous learning and competencies. Dominio las Ciencias,, 3(1), 241-253.
Yarzábal Coronel, N., Ávila Ávila, L., Álvarez Cedillo, J., & Núñez Navarrete, O. (2022). STEAM AND HACKATHON AS STRATEGIES FOR 21ST CENTURY SKILLS FOR EDUCATION 4.0. Mexico: ETM Editores Mexicanos.