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IMPLEMENTATION OF A STEAM EDUCATIONAL ECOSYSTEM FOR THE DESIGN OF PROJECTS ALIGNED WITH THE SDGS IN STUDENTS AT THE UAA SECONDARY EDUCATION CENTER

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Abstract: Within the framework of contemporary educational transformation, this article documents the design and implementation of a teaching ecosystem based on the STEAM approach, focused on the comprehensive training of upper secondary school students through projects aligned with the Sustainable Development Goals (SDGs). In this proposal, implemented at the Center for Secondary Education of the Autonomous University of Aguascalientes, articulates teacher training, student interests, and the use of disruptive technologies together with active learning methodologies to foster creativity, social awareness, and real-world problem solving. The ecosystem is structured around three pillars: prior student work, specialized teacher training, and interdisciplinary monitoring of projects within a real-world context. Two types of experiences are presented: introductory and exploratory STEAM projects, which have generated positive results in both student learning and social engagement. The findings underscore the need to strengthen institutional infrastructure and diversify teaching strategies to consolidate this ecosystem as an innovative and sustainable educational practice.
Keywords: Teaching Ecosystem, STEAM Approach, Upper Secondary Education, Maker Culture, Sustainable Development Goals.

INTRODUCTION

The STEAM approach has gained relevance as a comprehensive educational response to the challenges of the 21st century, promoting interdisciplinary skills, creativity, and critical thinking. In South Korea, its implementation from basic education to upper secondary education has fostered student innovation (Lee and Kim, 2021).

In Latin America, Colombia stands out with its Colombia Científica program, which coordinates educational projects based on real challenges and active methodologies, developing collaborative skills and applying knowledge to social reality (Ramírez and García, 2021). Ecuador, for its part, has aligned STEAM with the SDGs, achieving excellent results in innovation (Silva, 2023).

In Mexico, the National Technological Institute has promoted projects in which high school students solve local problems through science, technology, and art, strengthening creativity, critical thinking, and school-community ties (Cordero et al., 2022). This strategy has also been extended to the New Mexican School (Márquez and Mata, 2024). Faced with the challenges of educational transformation, the Centro de Educación Media Plantel Oriente Turno Vespertino of the UAA recognizes that STEAM links academic knowledge with social, technological, and environmental realities. This paper presents the design, implementation, and evaluation of a teaching- y ecosystem based on active methodologies, maker culture, and emerging technologies (UAA, 2023), with the aim of fostering creativity, social awareness, and contributing to the achievement of the SDGs.

THEORETICAL FOUNDATIONS

The STEAM educational ecosystem proposal integrates cross-curricularity, active learning methodologies, and multiple intelligences to promote interdisciplinary, critical, and contextualized education. Its objective is to articulate knowledge from different areas, promoting critical thinking and learning based on real-world problem solving (García, 2022). This integration is achieved through educational alignment with learning objectives, facilitating the development of cognitive and socio-emotional skills from a holistic perspective (Amores and de Casas, 2019). Educational transversality, together with *"design thinking"* (Vázquez and Mendoza, 2024), allows academic content to be connected to everyday contexts, encouraging critical reflection and the practical application of knowledge. This approach requires teachers to adopt new teaching strategies that motivate students, recognize their diversity, and promote the transfer of skills through the use of emerging technologies (Arteaga, 2023).

The teaching ecosystem is a complex and dynamic educational environment in which students, teachers, the community, and technologies interact independently (Otoya and Tubay, 2021). Based on Bronfenbrenner's technological ecosystem model, this ecosystem is built on different levels, allowing for a broad and comprehensive understanding of the educational process. Among its most notable qualities are interconnectivity, interactivity, interdisciplinarity, and student autonomy (Florido and Alcocer, 2023), as well as the use of active technologies and methodologies, thus promoting meaningful learning in a real-world context and the ability to foster comprehensive training from an inclusive, collaborative, and equitable perspective. It also allows for the development of teaching skills aligned with the Sustainable Development Goals (Morchón et al., 2020).

Maker culture is based on the "*do it* yourself" principle, integrating digital technologies, active methodologies, and collaborative work, favoring student participation as the protagonist in the construction of knowledge, allowing the development of cognitive, socio-emotional, and digital skills even in conditions of technological scarcity, through accessible materials and inclusive strategies (Hu and Gong, 2022).

With regard to Information and Communication Technologies (ICT), it is very important to combine all the technological elements around the teaching proposal in a balanced way under the STEAM approach (Tofel-Grehla et al., 2023). Augmented Reality (AR) combines physical environments with interactive digital elements, improving student performance (Rizo, 2022). Its use facilitates the understanding of complex content, increases student motivation, and promotes meaningful learning. In addition, it improves information retention, stimulates critical thinking, and favors different learning styles. AR, together with other 3D design resources, represents an effective way to modernize teaching practices and prepare students for advanced technological contexts (Castro and Delgado, 2021). However, the challenge in teacher training, the lack of adequate materials, and resistance to using active methodologies, as well as the incorporation of disruptive technologies, generate various areas of opportunity (Pérez, et al., 2023).

The theory of intelligences challenges the traditional notion of intelligence as something static, unitary, and encyclopedic, seeking an appropriate balance between emotional management, socialization, creativity, and innovation (Espinosa et al., 2021), resulting from a balance between various combinations of intelligences, allowing special skills to be channeled into innovative problem solving, the acquisition of new knowledge, and the implementation of ideas (Quílez and Lozano, 2020). By incorporating different activities into projects, the individual needs of students are met, stimulating curiosity and avoiding traditional lectures that tend to foster apathy and boredom in students (Macías-Coronel, 2023).

The STEAM approach (Science, Technology, Engineering, Arts, Mathematics) brings together the methodological qualities needed to integrate the didactic-methodological and cognitive aspects of the student (ISTIE, 2019). The *Science Foundation Arizona* (2017) classifies STEAM models into four categories based on their degree of immersion in the integrated approach of according to their curriculum. Each model varies according to the complexity of the projects as well as the ways of working, infrastructure, and how the approach is implemented (Lam-Byrne, 2023). This research project focuses on two models.

The Introductory Model is found in traditional classrooms with occasional activities. The core subjects of science, technology, engineering, and mathematics are taught in a partial manner but with practical examples in each area or subject. In the Exploratory Model, students develop STEAM skills through tasks that combine two or more disciplines, using problem-based learning or more extensive challenges such as projects focused on the Sustainable Development Goals, which include data collection (mathematics) and solution design (engineering). Here, students organize their sessions and activities, developing research and collaboration skills.

METHODOLOGY

This project began with the implementation of the ecosystem model with the participation of teachers specialized in STEAM teaching, the use of active learning methodologies, the recovery of previous student work, and finally its implementation in real-world problem solving. Subsequently, a descriptive-interpretative qualitative approach was applied using a Likert scale according to (Oviedo et al., 2022), focusing on a sample of five students from a universe of 15 in the fourth semester, who worked on projects within a teaching ecosystem at the Secondary Education Center of the Autonomous University of Aguascalientes, East Campus, Afternoon Shift, to analyze the scope, satisfaction, and impact of STEAM teaching on students.

Design of the educational ecosystem: The educational ecosystem is made up of three pillars: the students' previous work, specialized teacher training, and monitoring under the STEAM approach through the application of prototypes in real life.

The *first pillar* focuses on the recovery of work previously done by students in different subjects, as well as work presented at institutional events aimed at the student community, such as science fairs, academic conferences, and entrepreneurial exhibitions. The purpose of this recovery is to give students the opportunity to evaluate the feasibility and applicability of their projects in solving real problems, promoting a tangible social impact.

The *second pillar* focuses on teacher training and updating, providing teachers with the necessary skills to identify, promote, and monitor collaborative, cross-curricular, and interdisciplinary work, within the framework of the maker culture and the STEAM approach. To this end, a refresher course was designed with the aim of contextualizing teaching strategies based on these approaches, through the careful selection of prototyping tools, augmented reality, and active methodologies geared toward the design of learning experiences in which design thinking is applied.

The course was structured in three units: (1) active methodologies under the STEAM approach; (2) *maker* technologies and tools; and (3) *maker* project design. The first unit introduces the pedagogical foundations, emphasizing their relationship with principles of neuroeducation, problem-based learning, action research, case studies, and the flipped classroom. The second unit addresses tools such as augmented reality with Merge, 3D printing, and digital design on free platforms such as Tinkercad. Finally, in the third unit, participants develop an educational project aligned with STEAM approaches and the Sustainable Development Goals, with a view to implementing it in the classroom during the corresponding semester.

The *third pillar* establishes that projects must respond to social and sustainable needs, addressed from an interdisciplinary and cross-cutting perspective. It also includes the identification of areas for improvement in prototypes through the application of *design thinking* principles.

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RESULTS

The main objectives sought after the implementation of the pedagogical ecosystem are:

To promote practical learning and the application of knowledge in STEAM areas through activities that link the Secondary Education Center with its social context, favoring meaningful teaching aimed at developing creative solutions to local problems.

To foster teamwork and interdisciplinary collaboration among students as a strategy for addressing challenges with a social and sustainable impact, while strengthening their vocation for learning and awareness of their role as agents of change.

Figure 1 outlines the structure of the ecosystem. Teacher training is represented by the yellow ring, previous work is represented by the blue ring, and contextualization in real-world problems using the STEAM approach is represented by the red ring.

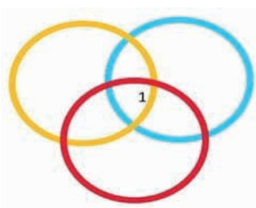

Figure 1. Structure of the proposed STEAM teaching ecosystem (own design).

The implementation of the teaching ecosystem made it possible to recover two projects previously developed by fourth-semester students, class of 2024, afternoon shift, East Campus, with the participation of a total of 15 students. Based on the models suggested by the Science Foundation Arizona and the curriculum of the Secondary Education Center, two approaches were structured within the STEAM model: an introductory one, entitled "Cklean Vision," and an exploratory one, called "Proyecto Limoncito."

The "Cklean Vision" project, developed by Ramírez et al. (2024), initially emerged as a physics assignment with the purpose of illustrating the Doppler effect. Its evolution led to the design of a proximity sensor for people with visual impairments. The prototype was given to a first-semester morning student from the 2024 class at the East Campus with visual impairment, who collaborated in its testing phase. Through her active participation, data was generated that provided feedback for the device improvement process, thus integrating elements of data science into the project. Figure 2 shows evidence of the progress made.

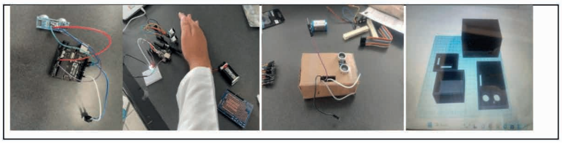

Figure 2. Evidence of the "Cklean Vision" project; introductory STEAM.

The "Limoncito Project" originated in the Evolution and Biodiversity course as a cross-curricular project. The context proposed by the students revolved around animal welfare, with the aim of raising awareness about the quality of life of companion animals. Chávez et al. (2024) focused their project on solving an orthopedic problem resulting from the accidental amputation of a limb in a rabbit by designing and implementing a low-cost prosthesis with the support of technological tools.

The prosthesis was donated to the animal's owners, and during testing, several areas for improvement in the prototyping were identified. Tools such as augmented reality provided by Merge and the 3D design platform Tinkercad were used to develop the device, allowing for an accessible and functional approach to the design process. Figure 3 shows the progress and adjustments made during the different phases of the prototype.

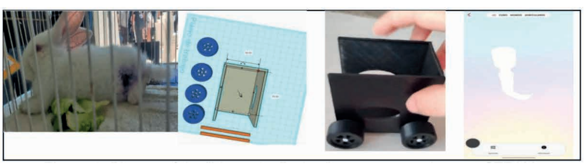

Figure 3. Phases of the "Limoncito Project" prototype; exploratory STEAM.

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At the end of the project, a survey was conducted using a 5-level Likert scale. The results were analyzed by thematic categorization. The results of the different aspects monitored in the survey are shown below.

a)Internal motivation for the love of learning.

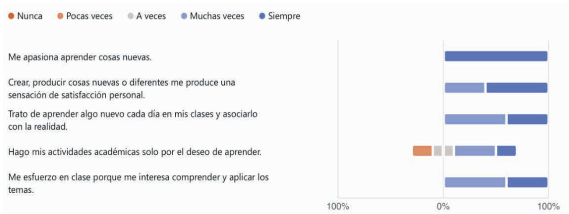

Table 1. Section 1: Internal motivation for the love of learning.

b)Internal motivation for the enjoyment of the task.

Table 2. Section 2: Internal motivation for enjoyment of the task.

c) External motivation due to parental control.

Table 3. Section 3: External motivation due to parental control.

d) External motivation for recognition.

Table 4. Section 4: External motivation due to recognition.

CONCLUSIONS

The implementation of the STEAM educational ecosystem at the UAA Secondary Education Center made it possible to establish an innovative pedagogical structure based on three fundamental pillars: the recovery of students' previous work, specialized teacher training, and the design of projects with an interdisciplinary and social focus. This strategy promoted the development of cognitive, socio-emotional, and technical skills by integrating active methodologies, maker culture, and emerging technologies, framing learning in real contexts aligned with the Sustainable Development Goals.

The "Cklean Vision" and "Proyecto Limoncito" projects demonstrate how the model can be adapted to different levels of STEAM depth—introductory and exploratory—and generate concrete impacts on the student and social community. The active participation of students in solving real-world problems, as well as the incorporation of tools such as augmented reality and 3D design, enhanced meaningful learning and intrinsic motivation to learn, as reflected in the results of the instrument applied.

Finally, the findings obtained underscore the relevance of consolidating this ecosystem as a sustainable educational practice. To this end, it is essential to strengthen the technological infrastructure, expand ongoing teacher training, and foster collaborative networks among teachers, students, and institutions. In this way, the proposal can be scaled up and replicated in other educational contexts, contributing to the transformation of upper secondary education from a critical, inclusive, and student-centered perspective.

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