TRANSFORMING EDUCATION IN COLOMBIA: DIDACTIC STRATEGIES, STEM, AND 21ST CENTURY SKILLS.

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Abstract

In the current educational context, it is imperative to evolve beyond mere information transmission and adapt to the demands of the 21st century. In this regard, the STEM (Science, Technology, Engineering, and Mathematics) educational approach has proven to be fundamental in equipping students with essential life skills.

This article presents a qualitative analysis of the didactic strategies implemented by teachers in the RUTA STEM program in educational institutions in Colombia, highlighting the educational transformation they are undergoing.

Furthermore, the need to tailor learning environments to the characteristics and demands of students is explored, emphasizing the relevance of a student-centered approach. Likewise, the article examines how the effective integration of educational technologies, supported by educational projects within the knowledge transmission strategy outlined by the RUTA STEM (STEM Tournament), can enhance STEM education and, consequently, the development of individuals competent in critical skills to face an increasingly complex world.

Key words: Didactic strategies, STEM, Information and Communication Technologies (ICT), 21st century skills, ATLAS.ti.

Resumen

En el contexto educativo actual, es imperativo evolucionar más allá de la mera transmisión de información y adaptarse a las demandas del siglo XXI. En este sentido, el enfoque educativo STEM (Ciencia, Tecnología, Ingeniería y Matemáticas) ha demostrado ser fundamental para equipar a los estudiantes con habilidades esenciales para la vida.
Este artículo presenta un análisis cualitativo de las estrategias didácticas implementadas por los docentes en el programa RUTA STEM en Instituciones Educativas de Colombia, poniendo de manifiesto la transformación educativa que están experimentando.

Además, se explora la necesidad de adecuar los ambientes de aprendizaje a las características y demandas de los estudiantes, subrayando así la relevancia de un enfoque centrado en el estudiante. De igual manera, se examina cómo la integración efectiva de tecnologías educativas, respaldada por proyectos educativos presentados en la estrategia de transmisión del conocimiento dispuesta por la RUTA STEM (Torneo STEM), puede potenciar la

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educación STEM y, por ende, la formación de individuos competentes en habilidades críticas para enfrentar un mundo cada vez más complejo.

Palabras Clave : Estrategias didácticas, STEM, Tecnologías de la información y comunicación (TIC), Habilidades del siglo XXI, ATLAS.ti.

I. INTRODUCTION

Contemporary education is not only focused in transferring knowledge, but in cultivating skills that prepare students to face the changing challenges of the 21st century (Ministry of National Education, OEA, et al., 2022). The STEM approach, integrating Science, Technology, Engineering and Mathematics, has become a fundamental pillar in the educational transformation in Colombia (Descamps Daw, 2019).

This article seeks to explore how the combination of didactic strategies with STEM can enhance the development of crucial 21st century skills. In this sense, the units of analysis that were part of the research project entitled '21st CENTURY SKILLS AND STEM EDUCATION: QUALITATIVE ANALYSIS OF THE DIDACTIC STRATEGIES OF THE ROAD STEM PROGRAMME IN COLOMBIAN EDUCATIONAL INSTITUTIONS WITH THE SUPPORT OF ATLAS.ti', are taken into account, as described below, based on different studies.

From the international sphere, the connection of new technologies with various human processes, especially in the field of education, is an important factor in the transformation of society. Research such as 'Technological skills of university students: a Latin American perspective' (Yañez-Figueroa et al., 2015) highlights the need for permanent qualification and continuous access to digital services to dissipate the technological gap. At the global level, 'Revolution 4.0, Competences, Education and Orientation' (Echeverría Samanes & Martínez Clares, 2018) highlights the importance of competences in order to face the future in the Fourth Industrial Revolution. Furthermore, 'STEM Education in Spanish-speaking

South America' (Tovar Rodríguez, 2019) underlines the relevance of the STEM approach in Latin America and its impact on students' acquisition of practical and transferable skills.

Likewise, in Colombia, research on didactics strategies, education, STEM and 21st century skills have earned relevance, especially in the post-pandemic context. Initiatives such as the 'ICT competencies model for teachers' (Hernández et al., 2016) seek to stimulate the creation of innovative educational environments in higher education. Similarly, 'Developing skills for the fourth industrial revolution through problem- and project-based learning methodologies' (Duque et al., 2018) highlights the importance of addressing current problems through training. ICT-related educational policies in Colombia are also analyzed in 'Educational policies of ICT in Colombia' (Rueda Ortiz & Franco Avellaneda, 2018), acknowledging the need to transform educational practices.

At the regional sphere, studies such as 'Educational robotics, Lego Mindstorms and Innobot, in the department of Nariño' (Canacuan Rosero, 2021) have shown that STEM methodology is effective in developing STEM skills in students. These studies emphasize the importance of implementing this methodology effectively in classrooms so that students can develop their learning capabilities and skills acquisition.

The linking of teacher training processes in relation to the STEM educational approach is crucial to improve education in different contexts and according to their needs. The inclusion of significant experiences at the national level allows us to identify participants who have contributed from their work as teachers to give continuity to this research. Projects such as the 'STEM Route' in Colombia, promoted by government entities and organizations', seek to stimulate the interest of children, adolescents, young people and teachers in the STEM field. These projects are designed to provide spaces that enable the approach and activation of emerging technologies to strengthen the skills necessary to face the fourth industrial revolution. Competitions and contests such as the 'STEM Tournament' are an integral part of this strategy, providing participants with the opportunity to present STEM projects and foster 21st century competences (Colombia learns, n.d.; Ministry of National Education, Fundaction Tecnalia Colombia, et al., 2022). In this framework, it is recognized the leading role of the teacher in the educational process and highlights the need to train teachers to effectively implement the STEM approach and use the necessary technological tools to carry it out.

A detailed analysis of the participation and development of STEM proposals in different regions of Colombia reveals a diversified and evolving panorama. The adoption and implementation of STEM programs and strategies vary significantly according to the region, showing challenges and advances in each one.

Colombian education policies and laws recognize the importance of STEM education for the country's development. Law 115, which regulates public education, emphasizes the need to develop critical and analytical skills to foster scientific and technological innovation, improve the quality of life and contribute to social and economic progress (Congress of the Republic of Colombia, 1994). Law 1753 of 2015 establishes the National Science, Technology and Innovation Policy, seeking to integrate advances in science and technology into productive processes and the solution of social and economic problems (Congress of the Republic of Colombia, 2015). The Ten-Year Education Plan 2016-2026 defines education policy and sets goals to improve the quality of education, including the promotion of STEM education as a key tool for social and economic development (Ministry of National Education, 2016).

In addition,Law 1874 of 2017 creates the National Network of STEM Territories with the objective of promoting STEM education in Colombia and training citizens with scientific, technological, engineering and mathematical skills (Congress of the Republic of Colombia, 2017). The National Science, Technology and Innovation Policy 2022-2031 seeks to strengthen the country's scientific and technological capacity, promoting innovation and economic and social development, highlighting the importance of the STEM approach (Consejo Nacional de Política Económica y Social CONPES (4069) Republic of Colombia & National Department of planning, 2021). In line with this, the Ministry of National Education (MEN) is leading an educational vision that includes standards, curricular guidelines and guides, promoting educational innovation and the use of digital technologies to improve 21st century skills (Colombia Learns, 2022). These measures underline Colombia's commitment towards the promotion of STEM education, highlighting its importance in fostering sustainable development and a major competitiveness in a world each time more driven by scientific and technological advances.

Education plays a fundamental role in the progress of society, and throughout its historical development, it has increasingly incorporated vital disciplines that today are recognized as STEM areas. These disciplines, once considered independent, have become an essential fusion that drives knowledge and innovation in society. In the Colombian context, the adoption of the STEM Education Approach has been fundamental in meeting the educational needs of the population, thus contributing to the country's development.

Integration of STEM in Education

To understand the STEM Education Approach in Colombia, it is crucial to examine its historical evolution (Echeverría Samanes & Martínez Clares, 2018; Gutiérrez Torres, 2020; Marín-Ríos et al., 2023; Ministry of National Education, OAS, et al., 2022; Ramos-Lizcano et al., 2022; Soo Boom NG, 2019; Yepes Miranda, 2020). Over time, education has undergone significant transformations to adapt to the demands and challenges of society. The conception of education as a driver of knowledge and innovation have led to the integration of subjects. This approach has been shaped by the need to train individuals capable of addressing the challenges of our time and promoting the advancement of society through solid STEM skills.

STEM education promotes active and meaningful learning by performing students' active participation in their learning process (NextGen STEM, 2021). The incorporation of technology and digital tools in the STEM approach is fundamental to enhance learning and foster creativity and innovation (García-Villaraco et al., 2021). The digital era in which we live demands that students acquire technological skills from an early age, and STEM education provides the space for this to happen in an integrated and meaningful way.

It is fundamental that educators, educational institutions and policymakers work together to promote STEM education and ensure that it is accessible to all students (García-Villaraco et al., 2021). This involves providing adequate resources, training and support, as well as creating environments conducive to active learning, creativity and innovation.

Didactics strategies for STEM teaching

Didactics strategies in the STEM educational approach are not simply techniques, but are intrinsically influenced by the teacher's educational philosophy, his or her vision of education, the pedagogical model employed and the curricular theories that underpin his practice. These strategies are manifested in the teacher's interaction with students, the organization of content, the choice of methods and resources, and the assessment of learning (Londoño et al., 2010). It is fundamental to understand that these strategies cannot be applied mechanically, but they must be adapted to the particularities of the students, the educational environment and the beliefs of the teacher (Londoño et al., 2010).

In the context of the STEM approach, it is essential that teachers strategically choose the most appropriate methodologies for their students and the specific educational context. Among the recommended strategies in this context are Problem-Based Learning (PBL), Challenge-Based Learning (CBL), Project-Based Learning (PBL), Inquiry-Based Learning (IBL), Cooperative Learning, Gamification, Design Thinking, and Engineering Design (Echeverría Samanes & Martínez Clares, 2018; Jauregui et al, 2018; Johnson et al., 1999; Ministry of Education, Culture and Sport Spain, 2015; Vinicio et al., 2020).

Problem-based learning (PBL) involves students collaborating to tackle real-life or simulated problems, applying their acquired knowledge and skills. This method fosters reflective and critical learning, with an integral view of knowledge, involving the community in decision-making on various issues (Vinicio et al., 2020).

On the other hand, Challenge-Based Learning (CBL) seeks to connect knowledge with real-life experiences, allowing students to integrate theory and practice by solving authentic challenges (Echeverría Samanes & Martínez Clares, 2018).

Similarly, Project-Based Learning (PBL) promotes the practical application of knowledge and skills through the resolution of real or simulated problems, strengthening the understanding of academic concepts and critical thinking (Ministry of Education, Culture and Sport Spain, 2015).

The Inquiry-Based Learning (IBL) approach places students in a central role, encouraging them to explore a topic autonomously, asking questions, collecting data and information, and analyzing them to reach their own conclusions (Echeverría Samanes & Martínez Clares, 2018). On the other hand, Cooperative Learning fosters students to work together in small groups to achieve common goals, supporting each other and sharing knowledge (Johnson et al., 1999).

Gamification, or the use of game elements in non-game contexts, and Design Thinking are strategies that enhance creativity and problem solving through iterative and user-centered approaches (Rodríguez-Martínez & et al., 2017). Likewise, Engineering Design aims to teach students to apply engineering principles and techniques to solve real-world problems (Ministry of National Education, OEA, et al., 2022).

Finally, the Flipped Classroom (FL) moves part of the learning process outside the classroom, allowing more time in class for direct interaction with the teacher and collaborative knowledge construction (Kanobel et al., 2019). This approach combines direct instruction with constructivist approaches, promoting students' motivation and engagement in their own learning process (Kanobel et al., 2019).

Each of these strategies offers unique approaches and benefits to foster meaningful and active learning in the STEM context, and it is crucial to adapt them according to the specific needs and goals of each educational setting.

21st century skills for the advancement of society

In a globalized and technological world, 21st-century skills have become essential to face the challenges of today's society. These skills include essential abilities such as critical analysis, problem-solving, originality, teamwork, effective communication and the responsible and effective use of technology. Within the educational sphere in Colombia, the promotion of these competencies has become a fundamental element of the STEM Education Approach, with the aim of preparing students to contribute to the social, economic and environmental progress of the country as engaged citizens. The Ministry of National Education et al. (2022) endorses the importance of STEM skills for success in the 21st century and emphasizes their strengthening as a key objective in current and future education. The 21st-century skills are grouped into ways of thinking, ways of experiencing the world, ways of working and tools for working. Among the ways of thinking, creativity, innovation, critical thinking, problem solving, and autonomous learning are highlighted as skills that reflect how people tackle challenges and make informed decisions (Alvaro et al., 2021).

The ways of experiencing the world refer to interaction with the environment and the use of technology, including the appropriation of digital technologies and computer competence (Álvaro et al., 2021). The authors also highlight that, in terms of work approaches, life and professional trajectory, personal and social responsibility, and citizenship participation such as local and global are considered. These aspects indicate how people interact with others and fulfil their roles in society. Finally, the skills necessary to work effectively with others are referred to as tools for working, encompassing communication and collaboration, which are essential skills for labor and personal success (Álvaro et al., 2021).

II. METHODOLOGY

This study is based on a qualitative approach, using the ethnographic method (Hernández Sampieri et al., 2014) to analyses in depth the didactic strategies implemented by teachers in the ROUTE STEM program. The use of the ATLAS.ti to realize analysis of the content of the information collected, allowing for a deeper understanding of the data and emerging patterns *(Analyses Your Qualitative Data With ATLAS.ti Web - ATLAS.ti, n.d.).*

Later, it is presented an overview of the research phases, according to Atıcı (2016), these phases can be integrated into:

Preparatory phase of the design

This phase is crucial to establish the basis of the research. The choice of qualitative methodology, especially in the context of ethnography, seems to be appropriate to understand in depth the educational practices and experiences of teachers in the STEM approach. Documentary review and literature analysis are essential to get an accurate understanding of the current state of knowledge in a given field.

Field work phase

Access to the research setting and careful selection of participants became critical steps. The active participation of teachers and STEM experts provided invaluable insights into the implementation of STEM education strategies and the development of 21st century skills, thus enriching the research process.

Information phase

The use of ATLAS.ti for qualitative analysis represents an excellent choice. The application of techniques such as inductive coding and categorization allows a deep and meaningful analysis of the data collected. Furthermore, the organization of data using bibliographic managers such as Mendeley

is complemented as a good practice to assure the integrity and accessibility of references.

III. RESULTS

The analysis of content realized with ATLAS.ti revealed that the combination of STEM strategies not only boost STEM-based learning, but also plays a fundamental role in cultivating competencies such as analytical skills, the ability to solve problems effectively, promoting collaboration and stimulating creativity in students.

STEM training routes provide teachers with a crucial opportunity to keep up-to-date and expand their knowledge in science, technology, engineering and mathematics. In a world in constant technological evolution, being aware of the latest trends and advances in these areas becomes an essential element in providing quality and relevant education to students (Ministry of ICT et al., 2021).

This specialized training prepared teachers to carry out STEM projects in their classrooms, equipping them with innovative and creative teaching methods that involve actively the students. These approaches not only enrich students' learning experience, but also prepare them more effectively for future careers in STEM fields (Ministry of National Education, Fundación Tecnalia Colombia, et al., 2022; Ministry of ICT et al., 2021).

In addition, the inclusion of teachers in these training programmers, which were required in advance of participating in the STEM tournament, ensured that all contestants had a robust foundation of knowledge and skills in the STEM field (Ministry of ICT et al., 2021). This ensured that the tournament remained a fair competition, and that the projects presented reflected a high standard in terms of quality and creativity.

The STEM Route established various scenarios of participation, from the range municipal to the national, playing a crucial role in the promotion and evaluation of projects related to this educational approach (Ministry of ICT et al., 2021).

During the STEM 2022 Tournament, an observation guide was used to collect detailed information about the projects submitted by teachers and students participating in the national training program Ruta STEM. This guide allowed for an enriching qualitative analysis of the projects, providing detailed insight into the contextual and qualitative aspects of each project (Ministry of ICT et al., 2021).

The projects that arose because of the implementation of the STEM Pathway evidenced a beneficial effect on both the advancement of STEM skills and knowledge and on the community. These projects also stimulated greater environmental awareness and promoted an entrepreneurial mindset, thus strengthening the connection between the educational institution and the surrounding community.

This evidence supports the notion that the implementation of STEM education strategies can generate social benefits, economic and environmental substances. It is crucial to highlight that the STEM Pathway incorporates a gender equity perspective by promoting equal participation of men and women in STEM disciplines. Furthermore, the incorporation of gamification as an educational tactic helps to increase students' motivation and engagement, which can have a significant impact on their learning experience. Finally, a focus on project or challenge work allows students to tackle practical challenges and apply knowledge in real-life contexts, thus fostering integral development.

By observing the example provided by the teachers participating in the STEM 2022 Tournament and consider their research processes and the results obtained, it can establish significant relationships between the didactic strategies implemented and the current motivations at different educational levels. This analysis supports the importance of adapting educational strategies to respond to the changing needs and demands of students in the STEM field, thus assuring effective and relevant education in this era technologically constantly evolving.

IV. DISCUSSION

The effective integration of STEM strategies in education is essential to prepare students for the modern Laboral world. These strategies not only foster the development of 21st century skills, but also foster an interdisciplinary approach to problem solving, which is essential to tackle the complex challenges of today's society.

The STEM+ approach emerges as a response to the need to tackle in an integral and contextualized way the training of students in different areas of knowledge and skills relevant to life and the labor world today and in the future. By integrating elements of science, technology, engineering, mathematics and other disciplines such as the arts and humanities, it

seeks to develop individuals with a broad and flexible vision that enables them to tackle complex problems and develop innovative and sustainable solutions.

This multidisciplinary integration also reflects the interconnected reality in which we live, where the problems and challenges we face are not limited to a single area of knowledge. For example, solving environmental problems requires not only scientific knowledge, but also design skills, understanding of complex systems and sensitivity to cultural and social aspects related to the environment.

STEM+ education fosters active and meaningful learning by encouraging students' active participation in their own learning process. Through methodologies that involve teamwork, problem solving and practical application of knowledge, students have the opportunity to develop critical skills such as critical thinking, creativity, effective communication and adaptability.

The incorporation of technology and digital tools in the STEM approach is fundamental to enhance learning and foster creativity and innovation. The digital era in which we live demands that students acquire technological skills from an early age, and STEM+ education provides the space for this to happen in an integrated and meaningful way.

In secondary education, the adolescents in full intellectual and emotional development find in strategies such as engineering design a route to explore their creativity and apply STEM concepts in innovative projects. Challenge-based learning resonates with their challenging spirit, prompting them to proactively overcome obstacles. Teachers when they use these approaches not only facilitate knowledge acquisition, but also guide students towards essential skills for their academic and professional future, providing support and motivation.

In secondary education, students are at a stage of consolidating their identity and interests. Cooperative learning provides them with opportunities to work in a team and value the diversity of skills in a project, while problem-based learning challenges them to seek real solutions, stimulating their critical thinking and decision-making. Teachers at this level must be facilitators of learning, helping to connect theoretical concepts with practical applications, integrating elements of gamification to increase motivation and, consequently, active students' participation.

In Primary Education, students are curious, with an open mind to explore the world around them. Strategies such as design thinking and project-based learning teach them to approach challenges with creativity and empathy, stimulating their imagination and problem-solving skills in an environment of play and discovery. Teachers at this level must be enthusiastic guides who encourage children's natural curiosity, incorporating elements of gamification to make lessons fun and engaging, making education an exciting and memorable experience for children.

The effective integration of STEM-related educational resources at different levels not only strengthens the understanding of scientific concepts, technological, engineering and mathematics, but also fosters essential skills as it is quoted above. It is fundamental that teachers are trained and willing to adopt innovative pedagogical approaches that integrate STEM of a transversal way in the curriculum having access to up-to-date and technologically advanced educational resources.

Ultimately, promoting STEM education goes beyond teaching prompt concepts; it involves nurturing a STEM mindset that stimulates curiosity and enthusiasm for lifelong learning. This approach prepares students to successfully face the challenges and benefit from the opportunities that the future holds. The visual approach from ATLAS.ti facilitated understanding of the interconnectedness between various key concepts and provided a clear graphical representation of how these relate in the context of the project, identifying meaningful patterns and trends for a deeper understanding of the data.

V. CONCLUSIONS

This research highlights the importance of strategically integrating didactic strategies around STEM into education to cultivate 21st-century skills. The Adaption of educational environments according to students' needs, in line with national educational projects, is essential to ensure effective and relevant educational development. The results have significant implications for the continuous improvement of education in Colombia and in other similar educational contexts, advocating for the conscious adoption of STEM technology and strategies as fundamental pillars in the formation of the 21st-century citizen.

The STEM education approach in Colombia represents

a significant evolution in education, embracing the historical integration of science, technology, engineering, and mathematics in teaching.

Continuing to explore and strengthen this integration in the education system is essential to prepare future generations for the challenges and opportunities of contemporary society.

The use of ATLAS.ti in the content analysis provided an enriching and detailed view of the data collected, thus supporting the results and conclusions presented.

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