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METODOLOGÍA STEM EN LA EDUCACIÓN SUPERIOR: TENDENCIAS ACTUALES, INNOVACIÓN Y APRENDIZAJE INTERDISCIPLINARIO

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ABSTRACT

Higher education has adopted STEM methodology as a comprehensive approach that combines pedagogical innovation, interdisciplinary learning, and the development of transversal skills. The effective implementation of STEM enhances technical skills, creativity, critical thinking, collaboration, and problem-solving, preparing students to face scientific, technological, and social challenges. The reviewed research highlights the importance of ongoing teacher training, interdisciplinary curriculum design, collaborative assessment, project-based learning, and community engagement. Furthermore, the integration of practical experiences, case studies, and community service programs fosters the application of knowledge, strengthens self-efficacy, and promotes inclusion and equity in diverse contexts. Together, these strategies solidify STEM education as a transformative educational model, capable of producing competent, adaptable professionals committed to innovation and social responsibility.

Keywords:

STEM methodology, higher education, interdisciplinarity, pedagogical innovation, transversal skills, collaborative learning.

RESUMEN

La educación superior ha adoptado la metodología STEM como un enfoque integral que combina innovación pedagógica, aprendizaje interdisciplinario y desarrollo de competencias transversales. La implementación efectiva de STEM potencia habilidades técnicas, creatividad, pensamiento crítico, colaboración y resolución de problemas, preparando a los estudiantes para enfrentar desafíos científicos, tecnológicos y sociales. Las investigaciones revisadas destacan la importancia de la formación docente continua, el diseño curricular interdisciplinario, la evaluación colaborativa, el aprendizaje basado en proyectos y la vinculación con la comunidad. Asimismo, la integración de experiencias prácticas, estudios de caso y programas de servicio comunitario favorece la aplicación del conocimiento, fortalece la autoeficacia y promueve la inclusión y equidad en contextos diversos. En conjunto, estas estrategias consolidan la educación STEM como un modelo educativo transformador, capaz de formar profesionales competentes, adaptables y comprometidos con la innovación y la responsabilidad social.

Palabras clave:

Metodología STEM, educación superior, interdisciplinariedad, innovación pedagógica, competencias transversales, aprendizaje colaborativo.

INTRODUCTION

Higher education has undergone significant transformations in recent decades, driven by the growing demand for scientific, technological, engineering, and mathematical skills that enable graduates to meet the challenges of complex and interconnected societies. The implementation of STEM (Science, Technology, Engineering, and Mathematics) methodologies in university settings has become a key strategy for promoting critical thinking, creativity, and problem-solving in multidisciplinary environments, fostering the development of professionals capable of effectively integrating into productive and research sectors (Suherman et al., 2025). This approach not only emphasizes the acquisition of technical knowledge but also underscores the importance of transversal skills such as collaboration, communication, and adaptability, which are essential in dynamic and globalized work environments.

In this regard, several recent studies highlight the relationship between university professors' teaching practices and overall student satisfaction in STEM courses. Abrahamsen et al. (2024) demonstrate that implementing interactive, active learning-centered pedagogical strategies leads to greater student engagement and a more positive perception of the educational process. These findings underscore that the quality of teaching depends not only on curricular content but also on professors' ability to integrate innovative approaches that foster participation and a deep understanding of concepts.

Innovation in higher education is also reflected in the adoption of collaborative assessment models, which enable more inclusive and reflective learning. Dinglasan & Weible (2025) point out that STEM faculty recognize the benefits of group and collaborative assessment, not only as a grading tool but also as a means to develop teamwork and critical thinking skills. This type of approach promotes the shared construction of knowledge and prepares students for professional contexts where cooperation and collaborative problem-solving are essential.

Furthermore, teacher training and institutional evaluation are key factors in the effectiveness of STEM programs. Wilson & Varma-Nelson (2025), in their internal evaluation of STEM Education Innovation and Research The SEIRI Institute emphasizes that programs integrating ongoing teacher training, applied research, and innovative pedagogical practices achieve superior results in terms of student learning and knowledge transfer. These initiatives highlight the need to align institutional policies with pedagogical strategies that foster educational innovation and the continuous professional development of STEM educators.

Another relevant aspect is the link between STEM learning and social responsibility through community service programs. Mahmud & Ismail (2024), in their systematic review on STEM service Learning experts highlight that student participation in community projects linked to science and technology enhances technical, socio-emotional, and ethical skills, as well as fostering meaningful interdisciplinary learning. Project-based education and its connection to real-world contexts allow students not only to internalize academic concepts but also to develop skills to address complex problems ethically and collaboratively.

Finally, pedagogical change in higher education requires an active commitment from faculty to their own professional development and self-evaluation. Samaras et al. (2019) show that self-study is an effective tool for engaging STEM faculty in educational transformation processes, promoting critical reflection on teaching practice and the adoption of innovative methodologies. This approach fosters the professional development of faculty and the implementation of educational strategies that respond to the demands of contemporary society, integrating technical knowledge, interdisciplinary thinking, and transversal skills.

In this way, STEM methodology in higher education represents a comprehensive approach that combines pedagogical innovation, interdisciplinary learning, and ongoing teacher training. Current trends show that successful programs depend on the interaction between quality teaching practices, collaborative assessment, community engagement, and critical reflection by faculty. This dynamic not only improves student satisfaction and performance but also prepares professionals capable of facing the scientific, technological, and social challenges of the 21st century.

The objective of this article was to analyze current trends in the implementation of STEM methodology in higher education, highlighting innovative practices, interdisciplinary learning, and strategies that strengthen the academic and professional training of students.

METHODOLOGY

This study was conducted using a qualitative-analytical approach to examine current trends in the implementation of STEM methodologies in higher education, as well as to identify innovative practices and interdisciplinary learning strategies. The research was structured in three complementary phases: a systematic literature review, a comparative analysis of teaching experiences, and an evaluation of institutional practices reported in recent studies.

In the first phase, a systematic literature review was conducted, focusing on scientific articles published between 2014 and 2025. Relevant research on STEM education in university contexts, pedagogical innovation, collaborative assessment, and community service programs was selected. Open-access, peer-reviewed academic databases such as ERIC, Scopus, and Web of Science were used. Science and JSTOR were consulted, prioritizing empirical

studies, systematic reviews, and institutional evaluations. Source selection considered criteria of currency, thematic relevance, and methodological rigor, ensuring that the results reflected contemporary practices in STEM education.

In the second phase, a comparative analysis of teaching experiences was conducted, focusing on identifying innovative pedagogical strategies, collaborative assessment models, and interdisciplinary learning approaches applied in different higher education institutions. Findings from studies exploring STEM faculty perspectives on teaching, group assessment, and professional self-evaluation were incorporated. This analysis allowed for mapping emerging trends and contrasting implementation approaches, highlighting effective practices and common challenges in teaching STEM disciplines.

service -based learning programs. learning) and interdisciplinary projects in university education. The benefits in developing students' technical and transversal skills were identified, as well as the elements that facilitate or limit the adoption of innovative STEM methodologies in curricula. This phase also included the consideration of continuing education and teacher self-study as key factors for the sustainability and impact of STEM programs.

The analysis was conducted using a descriptive-interpretive approach, combining the synthesis of empirical findings with critical reflection on trends, successful practices, and areas for improvement in university STEM education. This methodology allowed for the generation of a comprehensive overview of the implementation of innovative pedagogical strategies, collaborative assessments, and interdisciplinary learning, contributing to an understanding of how universities can optimize STEM training and prepare students for contemporary scientific and technological challenges.

DEVELOPMENT

Higher education has adopted STEM methodology as a strategic axis to foster innovation and interdisciplinary learning, recognizing that contemporary challenges require professionals capable of integrating knowledge from science, technology, engineering, and mathematics with transversal skills. According to Suherman et al. (2025), STEM education not only develops technical competencies but also enhances creativity, computational thinking, and the ability to solve complex problems—essential skills in an increasingly competitive and globalized work and academic world. Evidence indicates that the effective implementation of STEM methodologies depends on the interaction of multiple factors, including teacher training, curriculum planning, student collaboration, and the integration of real-world learning contexts.

A central aspect of STEM implementation is the relationship between teaching practices and student satisfaction. Abrahamsen et al. (2024) found that the quality of teaching, the clarity of learning objectives, and the use of active learning strategies significantly increase students' positive perceptions of STEM courses. These results suggest that pedagogical innovation should focus on the student experience, incorporating hands-on activities, collaborative projects, and resources that facilitate interdisciplinary understanding, going beyond theoretical content.

Collaborative assessment is another key component that contributes to effective STEM learning. Dinglasan & Weible (2025) highlight that teachers value the use of group tests and shared assessments not only as a means of grading, but also as a tool for developing teamwork and critical thinking skills. Implementing these strategies allows students to construct knowledge together, fostering individual and collective accountability, while promoting essential competencies for professional environments where collaboration is indispensable.

Teacher training and development are fundamental pillars for the sustainability of STEM programs. Wilson & Varma-Nelson (2025) report that institutional programs that combine ongoing teacher training, applied research, and innovative pedagogical practices achieve positive impacts on teaching and learning. Similarly, Samaras et al. (2019) emphasize that self-study and critical reflection allow teachers to identify areas for improvement, adapt pedagogical strategies, and transform their teaching practices. This professional development of teachers is essential to maintaining the quality of STEM education and ensuring that students develop comprehensive and transferable skills.

Service-learning and interdisciplinary projects have also become established as an effective strategy for linking STEM content with real-world contexts and social problems. Mahmud & Ismail (2024) demonstrate that STEM service programs Learning experiences foster not only technical and analytical skills, but also socio-emotional, ethical, and collaborative competencies. By participating in community projects, students apply knowledge practically, strengthen their sense of social responsibility, and develop skills to address complex problems from an interdisciplinary perspective. This approach reinforces the idea that STEM education is not limited to the acquisition of knowledge, but also involves the holistic development of the student as an agent of change.

Furthermore, recent literature shows that pedagogical innovation in STEM higher education requires a flexible and adaptable approach that combines active methodologies, collaborative projects, and diversified assessment strategies. Integrating practical experiences, group assessments, and critical reflection fosters more inclusive, participatory, and motivating learning environments, contributing to student retention and the strengthening of their competencies (Abrahamsen et al., 2024; Dinglasan & Weible, 2025). This interdisciplinary vision promotes connections between different areas of knowledge, fostering deep and meaningful learning that transcends the boundaries of traditional disciplines.

Various international studies have shown that implementing STEM methodologies in higher education requires a comprehensive approach that integrates pedagogical innovation, interdisciplinary learning, and student-centered assessment. These studies demonstrate that the success of STEM programs depends not only on technical content but also on faculty preparation and motivation, the design of meaningful learning experiences, and the development of transversal skills such as critical thinking, creativity, and collaboration.

Through strategies such as interdisciplinary projects, case studies, and service-learning, students can integrate theory and practice, tackle real-world problems, and develop essential professional skills. This international evidence highlights that effective STEM education combines innovation, active participation, and engagement with the academic and professional community, establishing itself as a transformative educational model adaptable to diverse contexts.

Winberg et al. (2018) conducted a critical review of the literature on teaching STEM disciplines in higher education, highlighting that teacher training in this area still faces significant challenges related to integrating innovative pedagogical approaches and promoting active learning. The study underscores that, while numerous studies exist on effective methodologies, the adoption of student-centered practices is uneven and largely dependent on faculty preparation, motivation, and experience. The authors emphasize that ongoing training, professional development, and the exchange of best practices are essential to strengthening STEM teaching and ensuring that students acquire technical and transversal skills that enable them to solve complex problems in an interdisciplinary manner.

Zavrel (2015) provides evidence on the effectiveness of the case study method in STEM graduate education, highlighting that its use increases active student participation, improves conceptual understanding, and fosters the practical application of theoretical knowledge. The article argues that case studies allow students to confront real or simulated scenarios that require critical analysis, decision-making, and collaboration, promoting the integration of knowledge from different disciplines. This pedagogical strategy strengthens students' ability to link theory and practice, while simultaneously developing fundamental professional competencies for their future performance in scientific and technological contexts.

Borrego & Henderson (2014) explore eight strategies for increasing the use of evidence-based teaching in STEM education, highlighting that implementing pedagogical changes requires both institutional support and teacher commitment. Their analysis shows that interventions such as training in active teaching techniques, mentoring, and systematic feedback are effective in promoting educational practices focused on deep learning. This study underscores that adopting evidence-based methodologies contributes to improving the quality of learning, increasing student satisfaction, and fostering a reflective approach to teaching, which is crucial for the success of STEM education at the higher education level.

Mezinska et al. (2024) present a design-driven innovation approach in STEM disciplines, emphasizing the role of transversal skills in university learning. The authors show that integrating skills such as communication, collaboration, and critical thinking within STEM programs not only enhances teaching effectiveness but also improves graduate employability. Furthermore, they highlight that design-based innovation allows instructors to structure learning activities in a way that enables students to develop technical skills while applying creative solutions to complex problems, promoting interdisciplinary and meaningful learning.

Zhumabay et al. (2024) investigated the impact of a STEM teacher training course on teachers' self-efficacy and classroom experience. The study revealed that training in STEM methodologies increases teachers' confidence in implementing innovative pedagogical strategies and facilitates the integration of practical and collaborative activities. Furthermore, the findings suggest that teachers participating in these courses tend to design more interactive courses, encourage student participation, and apply diverse assessment techniques, thus consolidating educational practices that promote interdisciplinary learning and a deeper understanding of the content.

Walton et al. (2024) evaluate the impact of STEM academic interventions on the college readiness of students from rural areas, demonstrating that structured and contextualized programs increase students' academic competence and motivation. The authors highlight that the implementation of hands-on workshops, personalized tutoring, and laboratory activities significantly contributes to closing readiness gaps and fostering interest in STEM careers. This study underscores the importance of designing inclusive pedagogical interventions that consider the specific needs and contexts of students, promoting equity and access to quality STEM education.

Lalujan & Pranjol (2024) explore project-based learning as a decolonized assessment method in STEM education, proposing that this strategy fosters student autonomy and the integration of interdisciplinary knowledge. The authors argue that projects allow students to address authentic problems from multiple perspectives, promoting critical thinking, creativity, and collaboration. Furthermore, they highlight that this methodology can replace rigid, traditional assessments, aligning learning with professional and social competencies, and strengthening inclusion and diversity in STEM academic environments.

Hedge (2024) addresses the persistence of STEM students in higher education, identifying individual, institutional, and pedagogical factors that influence retention. His

analysis shows that academic support, early guidance, and the implementation of active teaching methodologies are crucial for maintaining student motivation and engagement. The findings indicate that building collaborative learning communities and providing faculty support are essential for students to identify with the discipline, strengthen their sense of belonging, and solidify their STEM career path.

Miao (2023) compares STEM education practices in universities in China and the United States, revealing differences in curriculum integration, pedagogical innovation, and the focus on transversal skills. The study shows that while some programs prioritize technical excellence and research, others emphasize practical application and interdisciplinary collaboration. These findings underscore the need for a balanced approach that combines technical knowledge, interpersonal skills, and practical experiences, promoting students' holistic development and adaptability to diverse contexts.

Abdi et al. (2024) conducted a bibliometric analysis of the evolution of STEM education, identifying research trends, international collaboration, and emerging areas of study. The analysis reveals a sustained increase in publications related to active methodologies, collaborative assessment, and interdisciplinary learning, highlighting the growing attention to pedagogical innovation and teacher training. This work demonstrates the global expansion of STEM education and provides a framework for future research and the development of educational policies aimed at strengthening university teaching in these disciplines.

Villa et al. (2026) examine how STEM-focused experiences during secondary education influence students' identity as "STEM people," finding that early exposure to hands-on projects, mentoring, and laboratories increases identification with the discipline and motivation to pursue STEM careers. This study highlights the importance of pre-university experiences in building competencies and career orientation, emphasizing the connection between early education, academic persistence, and success in higher education.

Rivera et al. (2025) modeled STEM career orientation among bilingual students, showing that individual, family, and institutional factors interact to influence career choice. Their study demonstrates that perceived academic support, self-efficacy, and participation in hands-on STEM activities significantly increase orientation toward these careers. These findings reinforce the need for inclusive educational strategies that consider linguistic and cultural diversity, promoting equity and participation in STEM fields.

Isenhour (2025) analyzes the impact of independent research projects in online STEM education, demonstrating that students who participate in autonomous research develop advanced skills in scientific reasoning, autonomy, and critical thinking. The study shows that integrating practical projects into virtual environments strengthens the understanding of complex concepts, fosters virtual collaboration, and improves preparedness for professional and academic challenges in remote or hybrid contexts.

Ku et al. (2025) propose a six-stage instructional design model for the collaborative implementation of integrated STEM education, called PADPIE (Preparation, Analysis, Design, Planning, Implementation, and Evaluation). This model offers a structured and practical guide for teachers, enabling them to systematically organize interdisciplinary activities, ensure the coherence of learning objectives, and comprehensively evaluate outcomes. The research highlights that a collaborative and sequenced approach facilitates the adoption of innovative practices, promotes teacher-student cooperation, and improves the effectiveness of STEM education in university settings.

After analyzing the contributions of these studies, it is considered that higher education in STEM disciplines has undergone a transformation driven by the need to develop technical, transversal, and interdisciplinary competencies. Innovative approaches have demonstrated that active learning, collaborative projects, and connections to real-world contexts allow students to apply theoretical knowledge practically, fostering creativity, critical thinking, and the resolution of complex problems. Teacher training remains a determining factor for the effective implementation of these methodologies, highlighting the importance of ongoing professional development, reflection on practice, and the adoption of pedagogical strategies that integrate both content and soft skills.

Learning experiences involving case studies, independent projects, and service-learning have proven particularly effective in strengthening students' self-efficacy, motivation, and engagement. These practices foster autonomy, collaboration, and the ability to analyze problems from multiple perspectives, contributing to the development of a strong academic identity in STEM and career persistence. Furthermore, early exposure to STEM experiences and contextualized guidance enable students to develop a sense of belonging and more clearly orient themselves toward career paths in these fields.

Assessment and instructional design have also evolved toward more flexible and inclusive models. Strategies such as collaborative assessment, project-based learning, and sequenced course planning facilitate students' integration of knowledge from different disciplines and the development of skills applicable in professional settings. The integration of evidence-based teaching methods and the adoption of structured models allow instructors to organize coherent activities, optimize learning processes, and promote active student participation.

Finally, current trends in STEM education show that innovation is not limited to content, but also encompasses

methodology, assessment, and engagement with the community and the professional world. Programs that combine hands-on experiences, the development of transversal skills, and institutional support foster deep learning, strengthen students' academic preparation, and promote equity and inclusion in diverse contexts. In this sense, STEM education is conceived as a comprehensive model that integrates theory, practice, collaboration, and creativity, with the goal of training professionals capable of addressing the scientific, technological, and social challenges of the 21st century.

Implementing STEAM methodology in higher education requires a strategic and structured approach that coherently integrates science, technology, engineering, mathematics, and the arts into the academic curriculum. This approach not only aims to develop technical skills but also to foster transversal abilities such as creativity, critical thinking, collaboration, and complex problem-solving. To achieve this, it is essential that universities carefully plan each component of the educational process, from course and project design to faculty training, teaching and assessment strategies, and engagement with the community and the professional environment.

The implementation of STEAM is conceived as a comprehensive process that integrates pedagogical innovation, interdisciplinary learning, and practical experiences, offering a solid framework to guide students toward meaningful learning and the real-world application of their knowledge. The essential aspects for effectively implementing this methodology are detailed below:

1. Interdisciplinary curriculum design

The effective implementation of STEAM requires a curriculum design that coherently integrates content across disciplines. This involves creating cross-curricular projects and subjects where students can apply knowledge from various areas simultaneously. Projects should be open-ended, contextualized, and geared toward real-world problems, encouraging collaboration among students from different disciplines. It is recommended to include an artistic and creative dimension to stimulate innovation and the ability to generate original solutions. Furthermore, planning should consider the progression of competencies, ensuring that students develop cognitive, technical, and socio-emotional skills gradually and in a structured manner.

2. Teacher training and professional development

Teachers are central to STEAM implementation, making it essential that they receive specific training in active methodologies, project-based learning, technology integration, and formative assessment. Professional development should focus on strengthening skills to guide interdisciplinary learning processes, foster creativity and innovation, and manage collaboration among students. Teacher communities of practice, educational innovation workshops, and mentoring programs are effective strategies for consolidating best practices and ensuring consistent, high-quality implementation.

3. Pedagogical strategies and active methodologies

The STEAM methodology promotes the use of participatory strategies, such as project-based learning (PBL), case studies, interdisciplinary laboratories, and service-learning. These strategies allow students to apply theory to concrete problems, develop research and critical analysis skills, and improve their ability to work in teams. Furthermore, the use of simulations, virtual environments, modeling software, and digital tools enhances the learning experience, facilitating the understanding of complex concepts and promoting technological innovation.

4. Comprehensive evaluation and feedback

Assessment in STEAM should go beyond simply grading theoretical content and consider transversal skills such as creativity, collaboration, communication, and critical thinking. It is recommended to use rubrics, self-assessments, peer assessments, and continuous feedback to foster reflection and deep learning. Project-based assessment and presenting results to external audiences help contextualize learning and strengthen the connection between theory and practice.

5. Links with the community and the professional world

An essential component of STEAM is its connection to society and the professional environment. This includes internships, community service projects, collaboration with businesses and research institutions, and participation in interdisciplinary laboratories. These experiences allow students to apply their knowledge in real-world settings, develop social-emotional skills, and understand the social and ethical impact of their career choices. Community engagement also strengthens the relevance of the curriculum and prepares graduates to perform effectively in complex and dynamic contexts.

To ensure successful implementation, institutions must foster an institutional culture of innovation, provide technological resources and collaborative learning spaces, promote teacher training, and establish mechanisms for monitoring and continuous improvement. Integrating the arts into STEM not only enhances creativity but also enriches the academic experience, enabling students to develop a comprehensive and flexible understanding of the challenges they will face in their professional careers.

CONCLUSIONS

Higher education is currently emerging as a space for innovation and pedagogical transformation, where the combination of interdisciplinary approaches, active methodologies, and collaborative assessment is redefining

the learning experience. Successful programs not only transmit technical knowledge but also promote essential transversal skills such as creativity, critical thinking, problem-solving, and collaboration. This integration allows students to address complex challenges holistically, strengthening their ability to apply knowledge in real-world and multidisciplinary contexts, a key requirement for training 21st-century professionals.

Teacher training and development are becoming a cornerstone of STEM methodology implementation. Well-prepared and committed teachers, dedicated to educational innovation, facilitate the adoption of strategies that enhance student participation, self-efficacy, and motivation. Reflection on practice, the use of structured models, and ongoing professional development enable the design of meaningful and coherent learning experiences, increasing educational quality and contributing to student retention and persistence in STEM fields. Thus, professional development for teachers becomes an essential catalyst for achieving academic excellence.

Furthermore, STEM education must consider the diversity of students and educational contexts, including early learning experiences, support for bilingual students, and rural environments. Integrating hands-on projects, case studies, and service-learning allows students to develop socio-emotional and ethical competencies, in addition to technical skills. This inclusive perspective ensures that STEM education is not only accessible but also equitable and capable of producing professionals who are aware of their social and scientific impact.

Innovation in STEM education transcends the classroom and extends into the academic community, research, and the professional world. The adoption of interdisciplinary strategies, decolonized assessments, and evidence-based approaches strengthens students' holistic preparation and fosters their ability to adapt to changing contexts. Higher education in STEM is thus presented as a transformative model that integrates theory, practice, collaboration, and creativity, with the goal of training highly competent, resilient professionals prepared to face the scientific, technological, and social challenges of today and tomorrow.

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Conflict of Interest:

The authors declare no conflict of interest.

Author Contributions:

Esmaeil Sadri Damirchi: Conception and design of the study, data acquisition, analysis and interpretation, manuscript drafting, critical content review, statistical analysis, and overall supervision of the study.

Ethical statement:

The study was based on the analysis of documentary sources and publicly available data, and therefore did not involve the direct participation of human subjects. No personally identifiable information was handled.