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CHARACTERISTICS OF EDUCATIONAL EXPERIENCES IN STEM EDUCATION IN MEDELLIN

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Abstract

STEM education seeks to respond to the challenges of the fourth industrial revolution and to prepare future generations of the city in 21st century skills and scientific and technological vocations. This article aims to identify the characteristics of the educational experiences lived in processes of partial and total implementation of the STEM approach. To this end, the article is located in the empirical-analytical paradigm, with a population of 2,511 teachers and 18,421 students from the 10th and 11th grades of 75 educational institutions in Medellín. The probabilistic random sampling (confidence level of 95% and margin of error of 5%) shows a sample of 390 teachers and 384 students. However, after filtering, data from 570 teachers and 3,262 students collected through a survey of 139 questions (Likert, dichotomous, polytomous, and multiple choice) were analyzed. The results allow identifying problem-based learning as the most implemented didactic strategy; the area of technology and information technology with the highest integration into the curriculum; the greatest uses of Information and Communication Technologies (ICT) are for communication and collaboration; the most implemented digital competencies are for surfing the internet and using email, and the partner with the most significant participation is the state, represented in different public and private organizations. Among the conclusions arises the need for a greater reflection and awareness of the processes and learning achieved by researchers and educational institutions to strengthen students' scientific and technological training.

Keywords – Educational experiences, Educational institutions, STEM education, Student perspective, Teacher perspective.

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1. Introduction

The fourth industrial revolution is framed in a historical context of major physical-digital technological transformations. These developments are causing the different sectors of society to change radically in the way they produce, consume, market, and work; therefore, they require more advanced scientific and technological skills from the new generations. This situation allows "[...] STEM education to emerge as a "good practice" in the learning process that will help students to gain knowledge more effectively" (Diamantopoulos, Brami & Spanos, 2018: page 9) through the implementation of active methodologies to develop skills such as critical thinking, creativity, problem-solving, and decision-making, necessary to meet the new demands of the information and knowledge society (Reinholz, White & Andrews, 2021).

STEM education promotes knowledge building by interrelating science and mathematics and developing an understanding of engineering and technology (McDonald, 2016). Sanders (2009) defines it as a unit of its component disciplines (science, technology, engineering, and mathematics), whose teaching and learning processes seek solutions to problems in the real world. In this sense, Zaher and Damaj (2018) state that "[…] students learn best when encouraged to construct and apply the knowledge they acquire through direct interaction with the world around them" (Zaher & Damaj, 2018: page 4).

In educational processes with a STEM approach, scientific knowledge is not reduced to interpretation from each discipline but to a global view from a diverse unit. On the one hand, Tsupros Hallinen and Shoop (2009) argue that STEM is based on a transdisciplinary paradigm that integrates disciplines, emphasizing what makes them common and complementary. On the other hand, Kennedy and Odell (2014) state that STEM education has become a meta-discipline, an integrated effort that breaks down traditional barriers between topics and, instead, focuses on innovation and the applied process of designing solutions to complex contextual problems using current tools and technologies. However, while this educational approach is studied from different perspectives:

> […] the understanding of what constitutes effective practice in STEM education and how to support it is still developing, as it is a brand-new field […] there is considerable uncertainty in how it is defined as well as the course activities and outcomes of this education. (Anabousy & Daher, 2022: page 529-530)

Therefore, it is essential to systematize and analyze the STEM educational experiences that are implemented to understand the characteristics of their development and, in this way, make visible their ways "[...] as an epistemic, methodological, ethical, and political commitment to producing knowledge in academic scenarios" (Rico & Cogollo, 2019: page 9). Reflection on the implementation of STEM educational experiences is important because "[…] it includes analysis of best practices, evaluations, examples, and case studies from the local and regional institutions" (Zaher & Damaj, 2018: page 4). This information provides insights into how these experiences can be improved and redesigned in more relevant and effective ways.

1.1. Importance of STEM Education

Since the 1970s, educational contexts have been reflecting on the need to establish an education that responds to the reality of the time, as well as the integration of the different disciplines of knowledge, which strengthens the development of skills, scientific literacy, and the development of critical thinking in children and young people. Faced with this scenario, "Good teaching practices and correct learning procedures of the STEM (Science, Technology, Engineering, and Mathematics) disciplines are essential factors in the motivation and training of professionals in society at the moment" (Grau, Reig, Puig, López & Rodríguez, 2015: page 1275).

Education must respond to global economic challenges, the demand for STEM literacy to solve global technological and environmental problems and focus on developing skills required in the 21st century (Domínguez, Oliveros, Coronado & Valdez, 2019). Among others, science education has a central role in this training based on six priority areas:

- Support for scientific thinking and encourage citizens to use evidence-based thinking.
- Provide adequate self-confidence, knowledge, and ability to be active citizens in a technologically determined world.

- Develop competencies that support problem-solving, innovation, analytical/critical thinking, and support for a responsible lifestyle.
- Teach young people and children to pursue scientific and technological careers, so that they can lead a full life, in a knowledge-based, innovation-intensive society.
- Enable European economic operators to have a duly qualified workforce, thus, creating an economic sphere that will enhance Europe's attractiveness.
- Encourage the active participation of citizens in scientific debates on the current problems of humanity and their solutions using science. (UE, 2015 as cited in Kersanszki & Nadai, 2020: page 63)

Additionally, Kelley and Knowles (2016) state that part of the success of the STEM educational approach lies in the teacher's level of mastery of the disciplinary content and its pedagogical management. In this regard, Shui and Cheng (2019) consider "[…] that teachers have developed a certain level of subject knowledge, pedagogical skills, and self-learning ability" (Shui & Cheng, 2019: page 63). And from this, they can integrate new technologies into their teaching as they have "[…] the necessary skills to develop their own high-quality classroom assessments or use resulting data to help make appropriate instructional decisions" (Mertler & Campbell, 2005, as cited in Sondergeld, 2013: page 152) to implement strategies and activities for the development of innovative curricula, which respond to the contextual needs and science and technology policies (Sondergeld, 2013).

The educational experiences of the approach "[…] enable students to self-assess their abilities and determine what types of education and careers they may seek in the future" (Ritz, 2012, as cited in Parker & Lazaros, 2014: page 25). That is, in addition to preparing them for the "[…] collaboration, critical thinking, problem solving, and digital literacy" (Parker & Lazaros, 2014: page 25), they also prepare them for "[…] developing their understanding on building materials, sensors, and control system. The students also learned physics concepts such as friction, lift, weight, thrust, drag, vortex, and stall… programming skills" (Shui & Cheng, 2019: page 63). This is an opportunity to reflect on the vocational orientation of young people (Sanabria-Rangel & Ospina-Díaz, 2023).

Among the skills highlighted in the scientific literature are students as problem solvers, innovators, inventors, self-sufficient, and logical thinkers, with a minimum technological literacy (Domínguez et al., 2019), as well as "[…] practical and create products in daily life" (Trung & Hong, 2019: page 203). For their part, Young, Carter and Bengtson (2020) mention other skills, such as the ability to inquire, to "[…] take risks and not being afraid to fail [...] try and then try again to solve a problem" (p. 13). Regarding self-regulated learning, for Langie and Pinxten (2018), skills such as "[…] motivation/persistence, time-management, concentration, etc." (Langie & Pinxten, 2018: page 11) are important for the appropriation of the concrete concepts of each experience as they develop life skills (Guanotuña-Balladares, Pujos-Basantes, Oñate-Pazmiño, Ponce-Jiménez, Carrillo-Llumitaxi, Delgado-Yar et al., 2024).

1.2. Characteristics of STEM Educational Experiences

STEM educational experiences cannot be defined nor understood from the simple literal definition of the acronym or etymology of the terms that compose it since, on the one hand, the experience is built by lived events (Beard, 2018). And on the other hand, this field demands an integrated and interdisciplinary vision of the knowledge that composes it in order to address the complex and diverse problems and situations of daily life with integrated solutions that combine multiple disciplines.

In the United States, organizations such as the American Society for Engineering Education (ASEE) and the National Academy of Engineering (NAE) propose that STEM educational experiences should focus on practical, interdisciplinary, and socially relevant aspects, not only to be implemented with those who choose a profession related to these areas but also as a way to provide STEM literacy for all (Brophy et al., 2008, as cited in Moore, Roehrig, Wang & Park, 2012).

For Johnson, Moore and Peters-Burton (2015), integrating STEM areas goes beyond teaching two disciplines together or using one as a tool to teach the other. Instead, they consider integration to be more intentional. It should be understood as teaching and learning processes of disciplinary knowledge content and practices, which include science or mathematics through the integration of engineering practices and relevant technologies.

In a documentary review of educational experiences with a STEM approach, regarding learning purposes, Ramos-Lizcano, Ángel-Uribe, López-Molina and Cano-Ruiz (2022) find a clear intention to develop the 21st century skills. They also identify that the need to use active learning strategies with creative and innovative teaching practices and integrate ICT as mediators and transversal in the training processes prevails. Finally, among the most recurrent success factors in educational experiences with a STEM approach, they find that the role of the teacher is crucial, as well as the involvement of the family, the community, and other external agents.

These trends are recognized as beneficial; however, Ramos-Lizcano et al. (2022) emphasize that it is necessary to work "[...] on the difficulties, risks, and challenges encountered in the implementation of the approach" (p. 352, translated quote from its original in Spanish) since, as Marcelo Caplan (López-Molina, Ramírez-Hoyos, Angel-Uribe, Escobar-Ortiz, Uribe-Zapata, Cano-Vásquez et al., n.d) points out, there are greater possibilities in informal education because it is common to find limitations in the school system.

STEM educational experiences are built with didactic strategies designed according to clear and intentional learning purposes, adjusted to the approach, with flexible procedures that teaching agents use to promote the highest quantity and quality of learning in students (Díaz-Barriga & Hernández, 2002). This requires the organization and planning of spaces, materials, and time, among others, and involves using methods, means, and techniques to achieve learning objectives (Salinas, 2004). According to Jolly (2016), the implementation of STEM-STEAM education in the classroom starts from six elements:

1. The integration of at least two areas of science, technology, engineering, and mathematics.
2. An education focused on real-world problems or engineering challenges.
3. An inquiry-based and student-centered approach to learning.
4. An engineering design process that leads to the development of a product or process to solve a problem.
5. Teamwork and student communication.
6. Development of rich, applied knowledge content in science and mathematics.

Although above these, "[…] problem-solving is really the heart of STEM investigations. Providing students with real-world problems to solve fuels their curiosity and investigative interests" (Jolly, 2012, para. 5). Nevertheless, for Duglio (2016), "[…] the STEM education approach seeks to achieve greater conceptual understanding from inquiry, with more active proposals from the point of view of learning, which represents visualizing learning from constructivism" (Duglio, 2016: page 2).

1.2.1. Didactic Strategies in STEM Education

Problem-based learning, project-based learning, computational thinking, inquiry learning, gamification, and design thinking, among others, are some of the didactic strategies implemented in STEM education. In this regard, Jolly (2014) states that STEM lessons focus on real-world issues and problems; are guided by the engineering design process; immerse students in hands-on inquiry and open-ended exploration; involve students in productive teamwork; apply rigorous math and science content while students are learning; allow for multiple right answers and reframe failure as a necessary part of learning.

Similarly, Hutton and Mis (2022) claim that these strategies should lead students to discovery zones to find solutions to real-world problems without forgetting that this approach is not designed to develop a subject area but to integrate the areas in a meaningful way. Moreover, for Fernández, Zúñiga, Rosas and Guerrero

(2018), they should include problem-solving through computational thinking based on four elements: decomposition, abstraction, pattern recognition, and algorithm design.

In general, research on the implementation of didactic strategies associated with STEM educational experiences concludes that active learning is a way for this to be developed according to the particularities of students as they respond to different learning styles and paces (Fernández et al., 2018; Maynard, García, Lucietto, Hutzel & Newell, 2021), they are inclusive and create motivation (Grau et al., 2015), the curriculum is enriched with activities in different contexts (García-Tort, 2024; Verma, Dickerson & McKinney, 2011), and they develop competencies for teamwork, research, creativity, communication, and leadership (Marín-Arrieta, 2024; Méndez & Alfaro, 2020).

1.2.2. The Learning Environments

Learning environments refer to situations, experiences, and spaces, physical and digital, created for the implementation of educational experiences in STEM education that, in general, are related to the workshop classrooms (makerspaces), museums, laboratories, and in diverse contexts as required by the nature of the projects being developed. This from "[...] a collaborative and flexible educational model, encouraging new learning models and skills through technologies" (Ferrada, Diaz-Levicoy & Puraivan, 2022: page 1)

In terms of infrastructure and physical equipment, "[…] one of the first things to consider is what types of tools, equipment, and furniture will be used in the newly designed instructional space. This should be driven by the curricular objectives and goals of the program or organization" (Love & Roy, 2018: page 34). In this sense, environments should be "[…] designed to cultivate multi-sensory learning environments to better address student auditory, visual, and kinesthetic learning styles' (Cheng & Feng, 2016: page 83), to 'apply learner-centered, experimental learning techniques' (Diamantopoulos, 2018: page 16) in order to 'model real-world contexts'" (West & Motz, 2017: page 20). These learning environments allow for knowledge construction in an active process guided by experimental challenges (Ferrada et al., 2022).

Regarding the conditions of the experience in these environments, Coello, Rodríguez, González and Hidalgo (2021) state that it should provide motivational support for the learning skills, "[...] develop skills in the field of communication, collaborative work, emotional intelligence, problem-solving, technical knowledge related to the work area for the purpose of interacting in professional environments" (Coello et al., 2021: page 3308).

1.2.3. STEM Integration Areas

One of the challenges related to programs on the use of scientific data is to find balance between the understanding of multidisciplinarity and the knowledge of a topic in depth (Allard & Cortez, 2013; Kelley & Knowles, 2016). This is because "[...] young people are required to acquire an integrated and interdisciplinary preparation of science and mathematics, particularly to understand complex problems in engineering, biology, environment, spread of diseases and epidemics, among others" (Bosch, Di Blasi, Pelem, Bergero, Carvajal & Geromini, 2011: page 133). Although this integration explores the possibility of including subjects between two or more of the STEM areas, it also makes it possible to involve other school subjects (Ángel-Uribe, Escobar-Ortiz, López-Molina, Ramírez-Hoyos, Uribe-Zapata, Vera-Muñoz et al., 2024; Sanders, 2009). But, especially concerning STEM areas, integration should aim to focus on the disciplinary knowledge of each one and address the points that converge between them (Daugherty, Carter & Sumner, 2021)

Besides the fact that this integration of areas allows knowing the principles of the disciplines, it is essential to create products that respond to the real-world needs (Trung & Hong, 2019). It is strongly related to educational innovation in teaching practice (Esquer & Fernández, 2020), is a means to generate meaningful learning (Roberts, 2021), and maximizes the potential of students to discover their strengths and prepare them to respond to the real-world needs (Ler & Wong, 2016).

1.2.4. Resulting Products

In this study, learning outcomes are particularly characterized in terms of functional products, prototypes, and software development. However, in every STEM experience, many possibilities emerge depending on the solutions built. For example, Jolly (2012) mentions products such as band instruments, electric Gamebox, confetti launcher, solar water heater, speedy shelter, etc.

Each STEM educational experience has different ways of configuring the processes and products of education according to their particularities, so it should be clarified that the most important thing is the process of building solutions that is developed, which require to "[...] investigate, design, create, and evaluate" (College of Engineering - University of Utah, 2017, as cited in Welling & Wright, 2018: page 19). Hence, rather than the resulting product, it is necessary to "1. Identify the problem or opportunity, 2. Devise a plan for solving the problem, 3. Implement/Evaluate the plan, and 4. Communicate the plan/solution" (Wright, 2012, as cited in Euefueno, 2019: page 8).

1.2.5. Actors Involved

STEM education involves its educational communities (teachers, students, principals, educational agents, parents, etc.) and institutions of various kinds that want to be part of the process and whose interest is the development of science and technology. That is, it links students' families, the productive sector, and higher education institutions (Fauber & Becker-Blau, 2020; Kennedy & Odell, 2014; Peterson, 2017), among others.

It also links groups excluded by racism (Harris, Dassopoulos, Sahl & Starostina, 2021; Lancaster & Jade-Xu, 2017; Lewis, 2015; Roberts, Maiorca & Chapman, 2019), queer communities (Friedensen, Kimball, Vaccaro, Miller & Forester, 2021) among others, such as students with diverse educational needs who find opportunities to develop their potential in STEM education. In this regard, Buitrago, Laverde, Amaya and Hernández (2022) state that it allows them to develop 21st century skills, respond in an assertive and motivated way, and enrich their own and collective learning.

This educational approach seeks to reduce marginalization and to promote inclusion in developing countries (Ching-Chiang & Fernández-Cárdenas, 2019). In the words of Ribble (2022), STEM experiences implement active-learning class that leads to better cognitive gains, better retention for students from underserved populations.

1.2.6. ICT Use in STEM Education

In particular, the use of technology in this study is related to the access to information and communication technologies in educational institutions. This includes, among others, electricity, equipment, technological infrastructure, and connectivity as enablers of interaction among participants and the development of the approach's processes and products. However, it is worrying that "[…] in a world where technology is ever changing through innovation, STEM classrooms appear to be left behind" (Pitler, 2011, as cited in Chacko, Appelbaum, Kim, Zhao & Montclare, 2015: page 1). Nevertheless, for Kefalis and Drigas (2019), it is possible to reduce this delay through the emergence of new educational paradigms by exploiting connectivity, increasing the means that can be shared online and developing cooperation among people away from one other.

In general, Latin America and the Caribbean have made progress "[...] in terms of the availability of technological equipment such as computers, cell phones, and home internet connectivity" (ECLAC, 2013, p. 31). However, the actors responsible for promoting better use of technologies in educational institutions are "[...] teachers, who can enable or facilitate students to make a meaningful use" of ICTs and [...] "school principals, who can exercise leadership so that these uses take place" (ECLAC, 2013: page 60). At the national level, "[...] the country has ICT for education programs and projects that aim to contribute to closing the digital divide [...] however, what has been done constitutes a good point of progress but does not imply an assured steady state" (UNICEF, 2014: page 12).

Since 2007, the Department of Education, with the Medellín Digital program, has provided resources and technological infrastructure and connectivity to the educational institutions of the municipality, but they [...] do not alone guarantee the total success of the appropriation process, so they require a long-term in-person and virtual support for sustainability (Rozo, Fuentes, Ruiz & Patiño, 2020: page 18). Other proposals support the region's future vision, such as the Development Plan "Medellín Futuro 2020-2023" (Mayor's Office of Medellín, 2020) which proposes a Valle del Software (Software Valley). Along the same lines, by the year 2023, the city will consolidate as the Special District of Science, Technology, and Innovation of Medellín (Mayor's Office of Medellín, 2022) that aims to have a social and economic impact.

However, despite recognizing the progress and efforts made, the conditions are not sufficient in all cases. The access, use, and appropriation of technologies continue to be the focus of attention to close, even more, the digital divide. Therefore, it is relevant to carry out studies, such as this one, that allow identifying the characteristics of STEM experiences and redefine them as part of a process to improve the quality of education in the district.

1.2.7. Skills Developed Through the STEM Approach

The concept of competence is linked to the development of skills necessary for real life applying the knowledge acquired. From the STEM approach, skills focus on recognizing problems/situations in context and contributing to building solutions from the disciplines. In this regard, Trung and Hong (2019) express that STEM educational experiences in which products are made promote the development of skills in students related to collaboration (sharing responsibilities and understanding the role of each group member) and creativity (improvement and refinement of products, problem-solving skill, devising different forms of solutions, testing different designs, improving solutions through experiments, etcetera).

These types of experiences prepare children and young people for the future, to not fear failure, to learn about a wide variety of fields of knowledge, to try new methods, to exercise their creativity, to take risks and challenges, to promote self-efficacy and self-esteem, to recognize their own talents, to develop competencies for discussion that allow them to defend and argue ideas, etc. In addition to trusting the developed criticality and transferring knowledge to real situations (Young et al., 2020). In the long term, these experiences allow students to apply the knowledge learned, "[...] assessing their career, interests, opportunities and development in the historical, present and future context, from the local scope to the globe" (Trung & Hong, 2019: page 203).

From another point of view, the design, implementation, and evaluation of STEM educational experiences allow teachers to strengthen their skills in the different dimensions that make up their work. Thus, disciplinary, pedagogical, and technological knowledge promotes the development of their abilities for self-learning and the meaningful integration of ICTs into their classes (Shui & Cheng, 2019), as well as higher-level critical thinking and problem-solving skills that guide students in recognizing the needs of their environment (Sondergeld, 2013).

Based on the findings mentioned above, this article seeks to present the characteristics of STEM educational experiences identified in the implementation of the approach in the city of Medellín. The aspects discussed include didactic strategies implemented, learning environments created, areas of knowledge integrated, products resulting from the training processes, actors intervening in the experiences, uses of technologies, and skills developed by teachers and students in these experiences.

2. Methodology

The data supporting this article are part of the first phase of the research project, which aims to identify the characteristics of educational experiences in processes of partial and total implementation of the STEM approach in the municipality of Medellín from the perspective of the teachers and student participants (Figure 1).

The paradigm on which the process is based is the empirical-analytical one, this "[…] is counted on the philosophical stance of natural scientist that is working with observable reality within society leading to production of generalizations" (Alharahsheh & Pius, 2020: page 41). Therefore, its approach is quantitative. Moreover, a survey-type instrument is used, which "[...] are useful for describing the educational phenomenon, but are also efficient for a first approximation to reality or for exploratory studies" (Torrado, 2004: page 233). A questionnaire containing 139 questions of various types (Likert, dichotomous, polytomous, and multiple choice with one or more answers) is used to collect information.

The population is made of 20,932 participants (2,511 teachers and 18,421 students) of upper secondary, academic, and technical education (10th and 11th grades) from 75 Educational Institutions (EI) of the Municipality of Medellín. These institutions are selected because they are classified at the highest levels of implementation of the STEM approach, according to two diagnoses made through the Department of Education of Medellín (Table 1) and to the implementation models of STEM/STEAM programs proposed by the Arizona STEM Network and the Maricopa County Education Service Agency (2017).

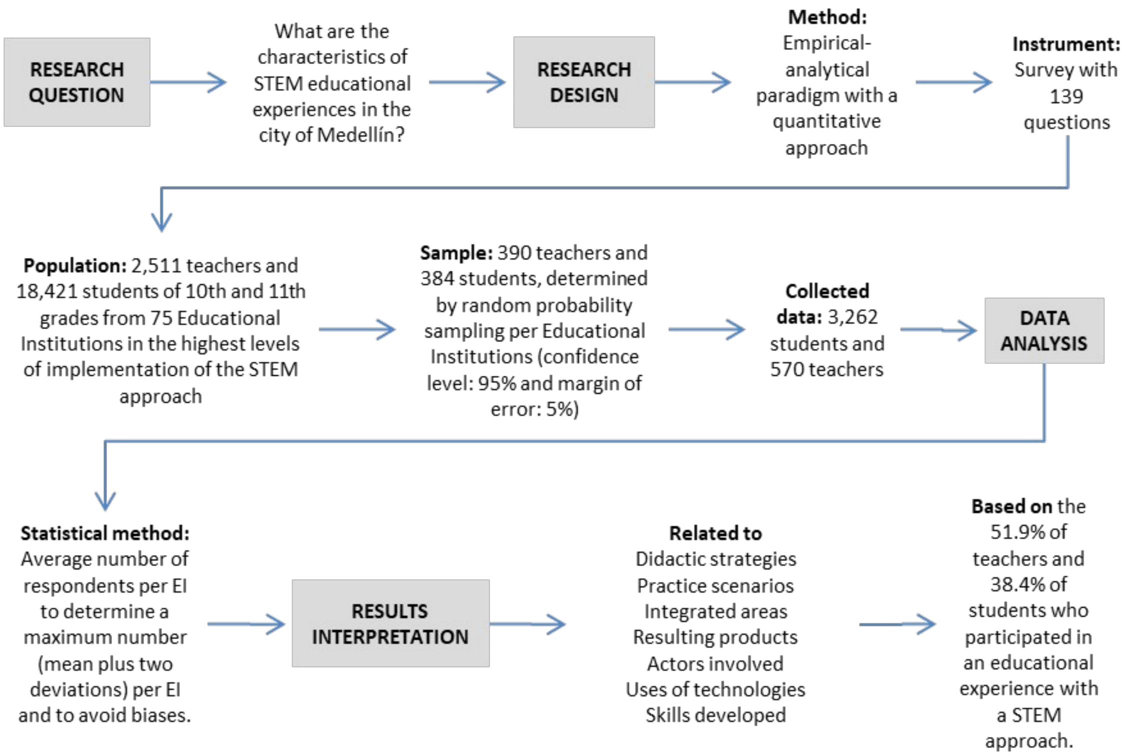

Figure 1. Procedure flowchart of the methodology used in the research project

Study Framework	Participants	Level of Implementation	# of EI	%
Medellín Territorio STEM+H (2018)	212 EI	Exploratory	44	20.75%
		Introductory	58	27.36%
		Partial immersion	14	6.60%
		Total immersion	15	7.08%
		None	81	38.21%
Marco Ser+STEM (2020)	81 EI	Exploratory	3	3.7%
		Introductory	18	22.2%
		Intermediate	45	55.6%
		Advanced	15	18.5%
		None	ND	ND

Table 1. Percentage of educational institutions according to the level of implementation of the STEM approach (Based on Cano & Ángel-Uribe, 2020, and Mova & Mayor's Office of Medellín, 2020)

The sample is composed of 390 teachers and 384 students from the selected educational institutions. It is determined by random probability sampling, per EI, to seek a balance among the resulting data. It has a confidence level of 95% and a margin of error of 5%. However, the application of the questionnaire far exceeded these numbers.

For the analysis, an estimate of the average number of respondents per EI is made to determine a maximum number (mean plus two deviations) per EI and to avoid biases. This process randomly excluded 203 respondents, resulting in a total of 3,262 students and 570 teachers for the analysis (Table 2).

	Surveys applied	Valid and refined surveys
Teachers	590	570
Students	3,445	3,262
Total	4,035	3,832

Table 2. Applied, valid, and refined surveys of the research

Of the total of 3,262 students surveyed, a slight majority (52.9%) are female, and 45.9% are male. Similarly, regarding teachers, 52.5% are female, and 46.8% are male. Less than 1.2% of students and 0.7% of teachers said they identified with another gender.

On the other hand, there is greater variability among teachers' ages: 33% of them are between 41 and 50 years old, followed by 23% who are between 51 and 60 years old. Whereas most students are between 16 and 20 years old (76.9%), followed by 22.8% who are between 10 and 15 years old.

Regarding participation in an educational experience with a STEM approach, 51.9% of teachers have done so, while 48.1% have not participated. Meanwhile, 38.4% of students say they have participated or are doing so, and 61.6% have not (Figure 2). In addition, both teachers and students (93%) express their willingness to continue participating in similar experiences.

Additionally, 75% of teachers and 77.7% of students who have not participated express their intention to do so in the future. This indicates that 11% of teachers and 13.8% of students have not yet participated and are not interested in doing so in the future. With these answers, the survey applied to those participants ended, since it was addressed only to those who have had these experiences. Thus, the results are presented only with the answers of teachers and students who have had them (Figure 2). That is, a total of 1,548 participants, of which 1,253 are students and 296 teachers.

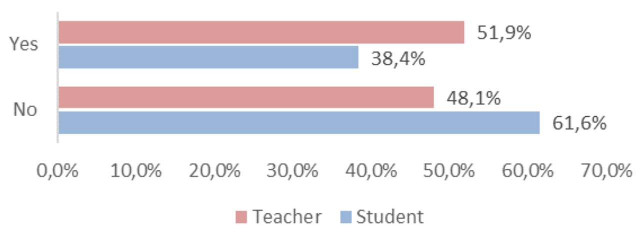

Figure 2. Percentage of teachers and students who have participated in experiences with STEM approach

3. Results

The analyses carried out for this article focus on the characteristics of the educational experiences related to didactic strategies, practice scenarios, integrated areas, resulting products, actors involved, uses of technologies, and skills developed by teachers and students in such experiences (Figure 3).

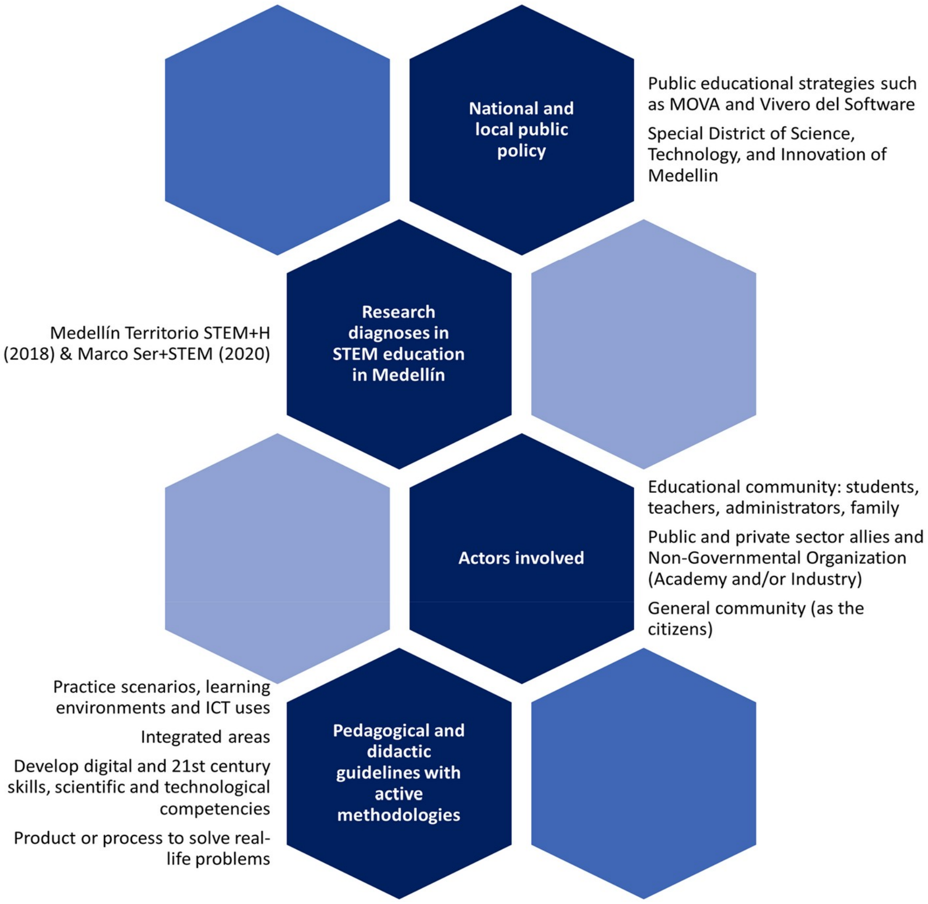

Figure 3. Medellín STEM Ecosystem for quality of education and learning outcomes

Regarding didactic strategies for active learning, it is found that the most used strategy is problem-based learning, and the least used is design thinking, with 84.3% and 58.1% of the students, and 89.2% and 42.2% of the teachers, respectively.

In most of the strategies, results are equal, but game-based learning and design thinking show the greatest difference between students and teachers. Interestingly, the percentage of students is higher than that of teachers (Figure 4).

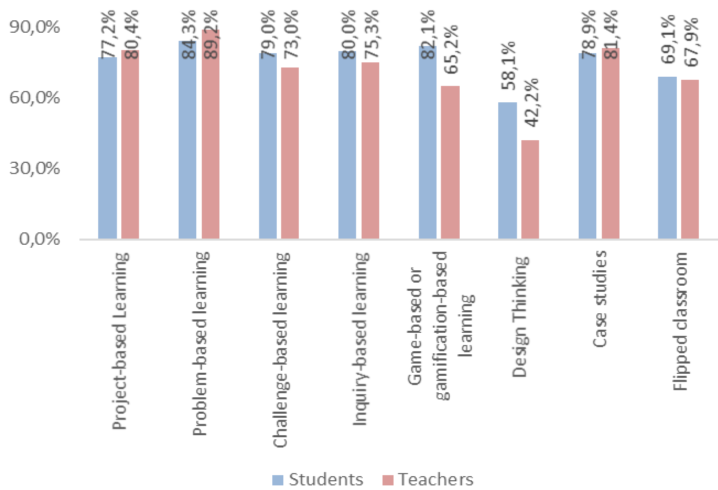

Figure 4. Percentage of teachers and students according to the active didactic strategies of STEM educational experiences in which they have participated

Concerning the scenarios in which they implement the strategies, most of the teachers (75%) mention the real context of the project. In comparison, 77.4% of the students mention the laboratories in higher education institutions. In the laboratory, the greatest difference between the two actors was found (Figure 5).

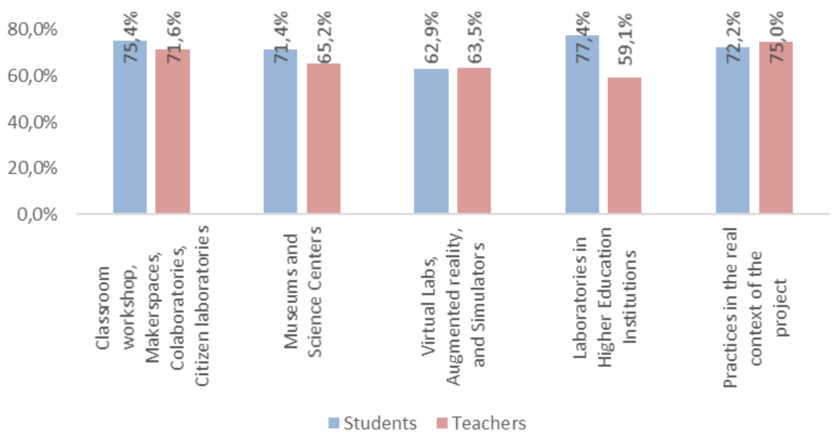

Figure 5. Percentage of teachers and students according to the learning scenarios of the STEM educational experiences in which they have participated

As for the areas, 87.8% of the students and 84.5% of the teachers recognize that technology and computer science are the most integrated areas in STEM experiences. In contrast, those showing less integration are the areas of religious education and physical education, recreation and sports with 47.5% and 61.7% of the students and 28% and 38.2% of the teachers, respectively. The recreation and sports areas have broader differences between actors, with a higher percentage of students than teachers' (Figure 6).

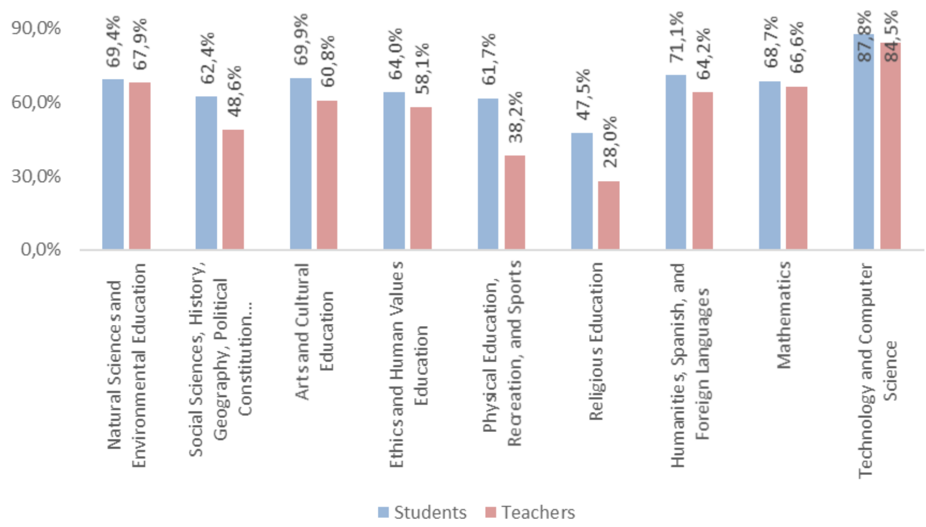

Figure 6. Percentage of teachers and students according to the areas integrated into STEM educational experiences in which they have participated

Regarding the types of products derived from the experiences lived, the results are different among actors; for most teachers (47%), the training process results were a functional product, and for 42.9% of the teachers, they were prototypes. These two characteristics are the most frequent. However, for 59.4% of the students, the result was software development. This result shows the greatest difference; again, the percentage of students is higher than that of teachers (Figure 7).

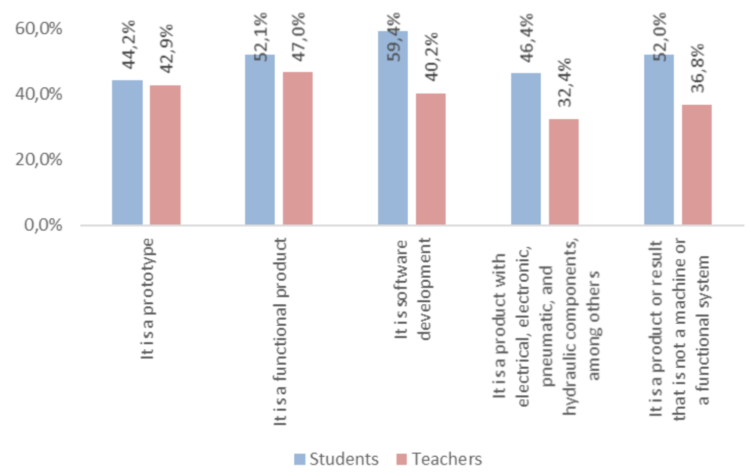

Figure 7. Percentage of teachers and students according to the products resulting from the STEM educational experiences in which they have participated

According to other actors involved in the experiences, partner institutions and family are very important. In this regard, it is found that, for teachers (75.3%), the most frequent ally of STEM experiences is the State, represented by actors such as Mova (the Teacher Innovation Center in Medellín), Vivero del Software (a space for technology and education in Medellín), the Department of Education, MinCiencias (Ministry of Science, Technology, and Innovation), the Ministry of Education, Ministry of Information and Communications Technology, and the Ministry of Labor, among others. While for students (63.7%), the most frequent actors are higher education institutions.

Further, teachers and students agree that the productive sector has the lowest presence, although with a significant difference of more than 11 percentage points (Figure 8).

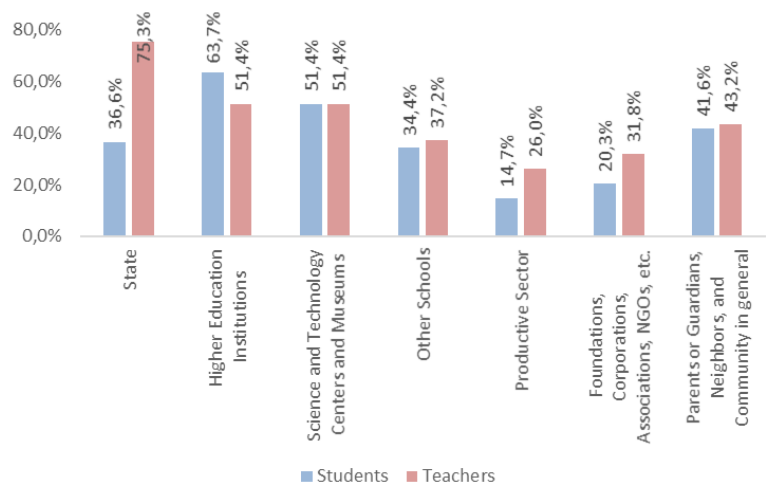

Figure 8. Percentage of teachers and students according to the participation of other actors in the STEM educational experiences in which they have participated

Concerning the teachers' and students' perception on access and connectivity issues, electricity is the resource to which they have the highest level of access (more than 91%). However, there are significant differences in their perceptions of permanent access to desktop computers, laptops, and the internet on teachers' computers. Contrary, there is a perception of non-existence of internet service for students' computers, with a similar percentage for students and teachers (Figure 9).

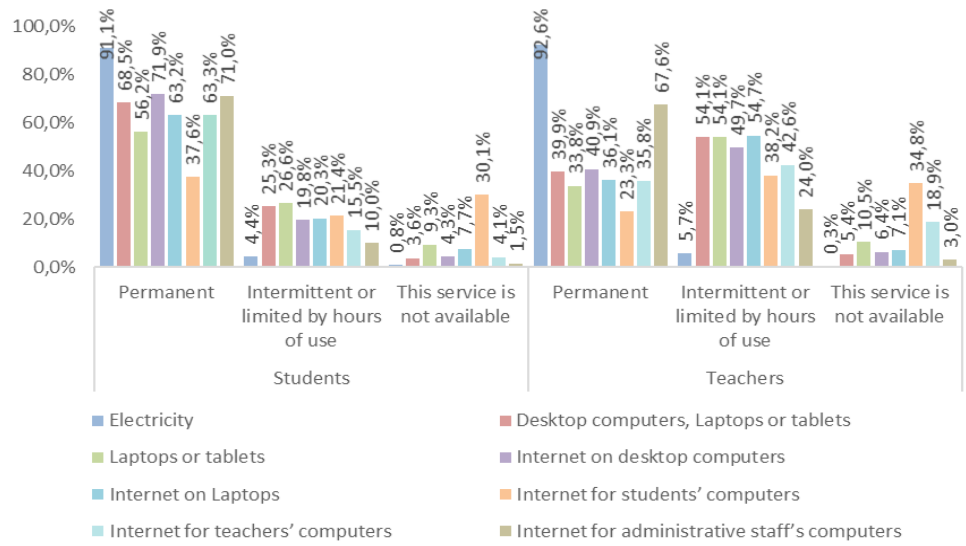

Figure 9. Percentage of teachers and students according to the access and connectivity to computers and various services they have in the STEM educational experiences in which they have participated

With respect to the devices, the percentage of teachers and students who have access to and use such devices is compared. The 3D printer, video camera, electronics kit, and robotics kit show a higher percentage of use by students, For the rest of devices, teachers' percentage is higher. The greatest difference in access and use between students and teachers is the Video Beam and the computer (Figure 10).

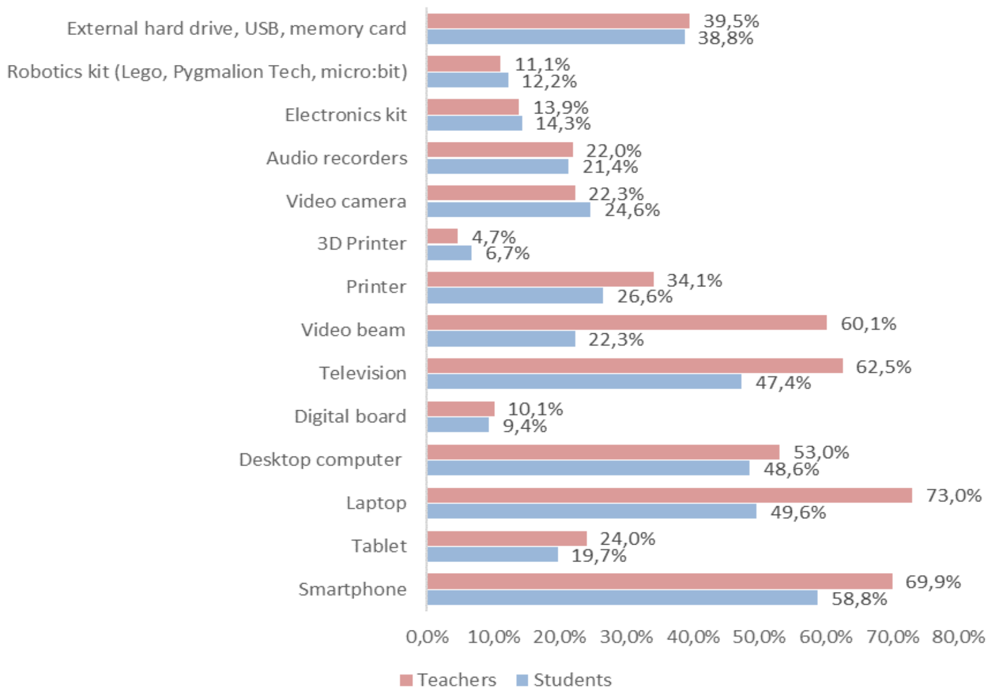

Figure 10. Percentage of teachers and students according to their access to and use of devices in the STEM educational experiences in which they have participated

Regarding the use of applications, platforms, and programs, it is evident that what is most used by students (72.9%) and teachers (93.6%) are programs to communicate with members of the work team and their networks. In contrast, the least used by students (42.8%) and teachers (68.8%) are those for testing, calculations, or projections (Figure 11).

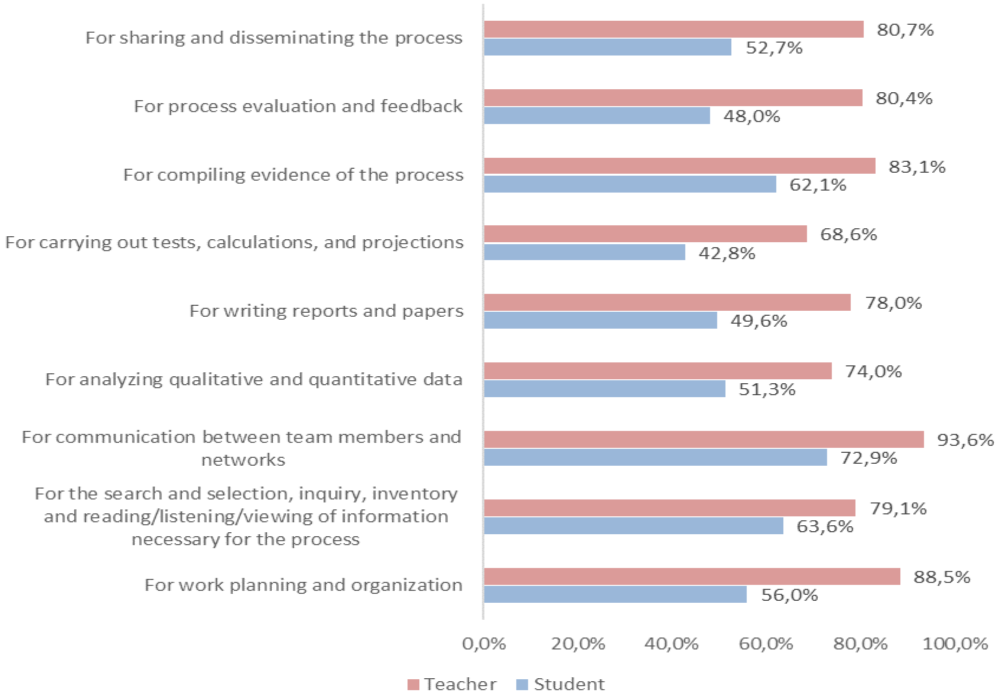

Figure 11. Percentage of students and teachers who use applications, platforms, and programs in the STEM educational experience according to the purposes of use

In relation to the level of autonomy for using applications, platforms, and programs, according to their purpose of use, students who know how to use them on their own (percentages above 70%) are those who use applications, platforms, and programs for communication among team members. This is followed by those who use them for search and selection, inquiry, inventory, and reading/listening/visualization of information necessary for the process. In turn, 35.9% of the students need a tutorial and 11.8% need help from another person to use them for testing, calculations, and projections (Figure 12).

Higher levels are observed regarding the autonomy teachers have for using applications, platforms, and programs based on their purpose of use. More than 80% of teachers use them "for communicating among team members," "for writing the process and reports," and "for work planning and organization." In turn, for analyzing qualitative and quantitative data, 32.1% of the teachers need a tutorial, and 7.4% need help from another person (Figure 13).

In terms of the frequency and places of use of the technologies in the STEM educational experiences, more than 82% of the students indicated that they most frequently use technologies at school, during the school day, and at home. Similarly, more than 75% of teachers express the same opinion. While for both, more than 62%, the use of technologies is less frequent in other places (Figure 14).

With respect to the competencies achieved in the educational processes with a STEM approach, there are, on the one hand, those related to the 21st century skills and, on the other hand, specifically, the digital competencies of the actors. The 21st century skills show a high self-perception of the actors on the competencies achieved and that they can put into practice in future experiences. A percentage higher than 97.3% of the teachers and 93.5% of the students consider that they have less developed competencies, such as the use of digital technologies for teachers and those of local and global citizenship for students. The responses that originally had a four-level scale between "Strongly agree" and "Strongly disagree" are grouped into two categories, "Agree" and "Disagree." Table 3 presents the classification of the 21st century skills, which takes up the one proposed by Fundación Omar Dengo (2014).

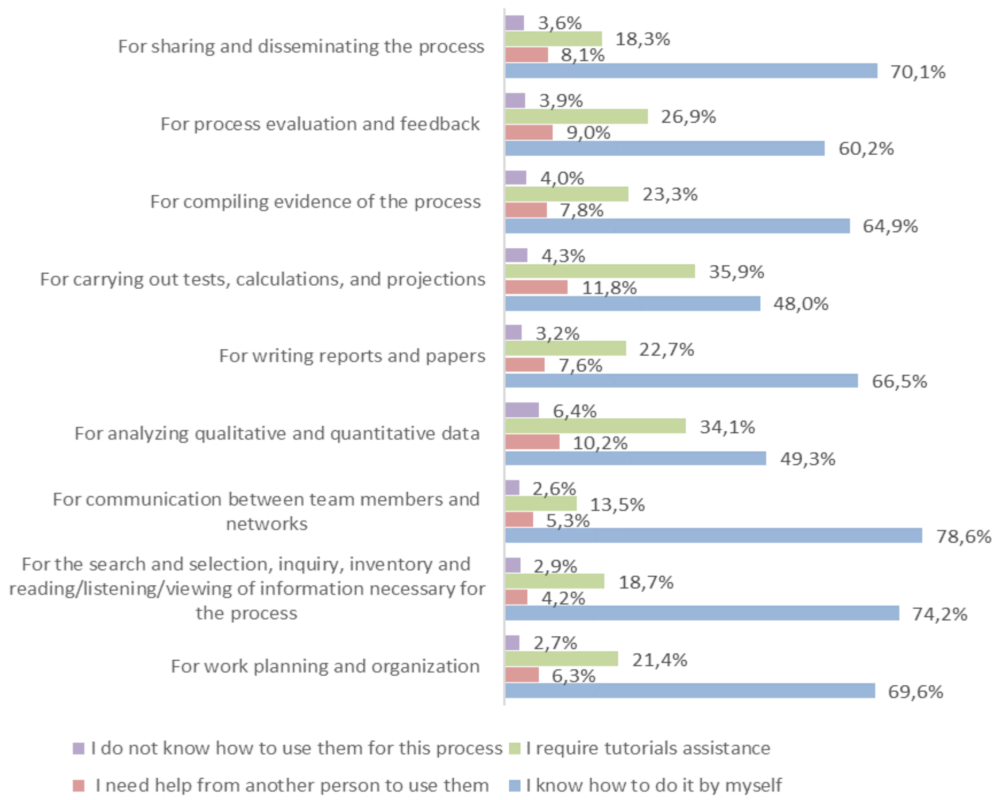

Figure 12. Distribution of students according to the level of autonomy they have for using applications, platforms, and programs based on the purpose of use

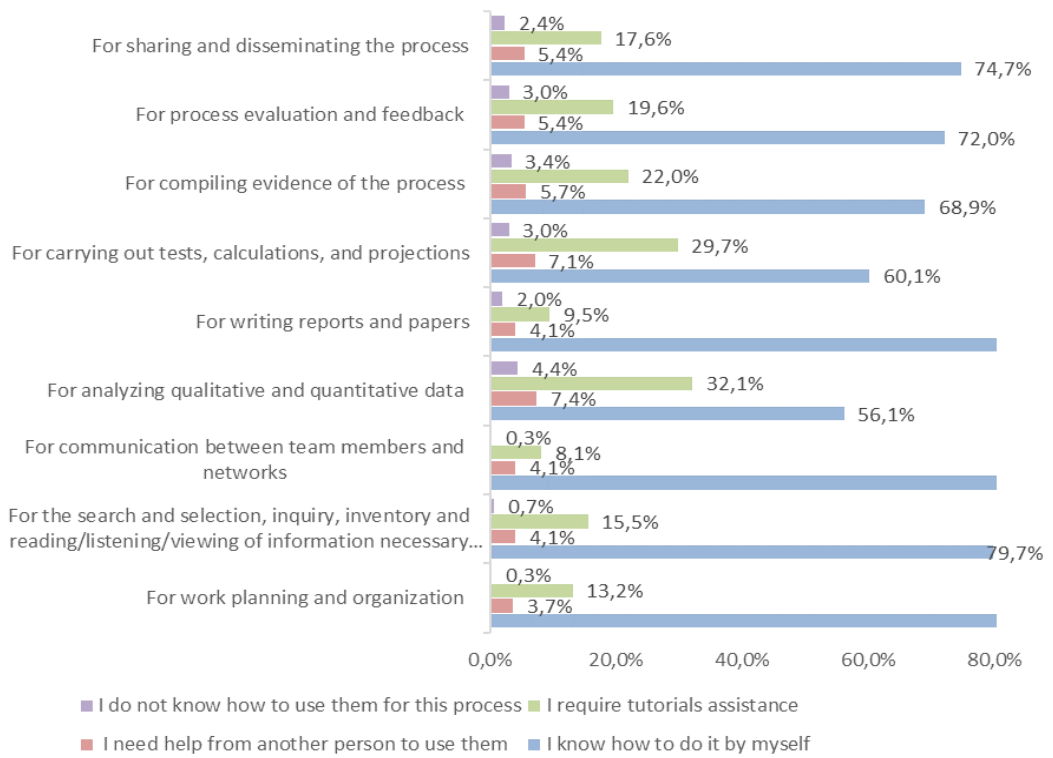

Figure 13. Distribution of teachers according to the level of autonomy they have for using applications, platforms, and programs based on the purpose of use

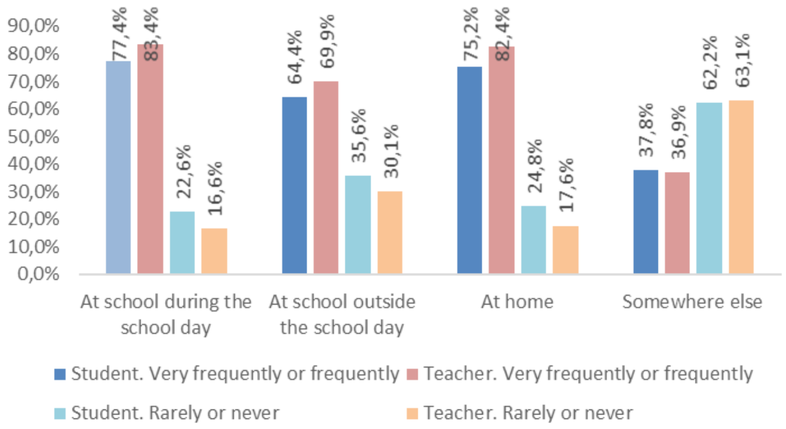

Figure 14. Distribution of students and teachers according to the frequency and place of use of technologies in STEM educational experiences

21st century skills		Teachers		Students	
		Agree	**Disagree**	**Agree**	**Disagree**
Ways of thinking	Creativity and innovation	93.3%	0.7%	96.2%	3.8%
	Learning to learn	99.3%	0.7%	98.6%	1.4%
	Critical thinking	99.7%	0.3%	97.5%	2.5%
	Problem-solving	99.7%	0.3%	96.8%	3.2%
Ways of living in the world	Local and global citizenship	100.0%	0.0%	93.5%	6.5%
	Life and Career	98.6%	1.4%	97.2%	2.8%
	Personal and Social responsibility	99.7%	0.3%	95.9%	4.1%
Tools for working	Use of digital technologies	97.3%	2.7%	94.9%	5.1%
	Information management	98.3%	1.7%	94.7%	5.3%
Ways of working	Collaboration	99.3%	0.7%	96.9%	3.1%
	Communication	99.3%	0.7%	96.4%	3.6%

Table 3. Distribution of teachers and students according to the 21st century skills achieved and that they can put into practice from the STEM educational experiences in which they have participated

As regards the digital competencies achieved, there is also a high self-perception by the actors. All teachers said they agreed or strongly agreed with navigating the Internet and using an email account. The use of an email account is also the most highly valued by 98.9% of the students.

On the contrary, the least valued was the use of interconnected digital devices to create a network between students and the teacher, by 84.1% of the teachers, and the fostering of a reciprocal flow of information among all members of the learning community, by 78.1% of the students. The fostering of a reciprocal flow of information presents the greatest difference between the two, with about 14.5 percentage points, this time, in favor of teachers.

As in Table 3, the responses that originally had four levels are grouped into two categories, "Agree" and "Disagree." Table 4 presents the digital competencies, adjusting what is proposed by UNESCO (2019) in the ICT Competency Framework for Teachers.

Digital competencies	Teachers		Students	
	Agree	Disagree	Agree	Disagree
Application of Digital Skills				
You use computer devices.	99.3%	0.7%	92.6%	7.4%
You create text documents using word processors.	98.3%	1.7%	94.6%	5.4%
You create multimedia presentations.	97.6%	2.4%	91.5%	8.5%
You create simple graphics.	93.2%	6.8%	86.4%	13.6%
You navigate the Internet.	100.0%	0.0%	97.3%	2.7%
You understand the basic principles of cyber safety/security.	97.0%	3.0%	91.8%	8.2%
You use a search engine to find resources and information.	98.0%	2.0%	95.6%	4.4%
You use an email account.	100.0%	0.0%	98.9%	1.1%
You identify and use software programs in the teaching and learning process.	92.6%	7.4%	89.5%	10.5%
You use communication and collaboration technologies.	99.7%	0.3%	98.7%	1.3%
You use social networks to communicate with the wider learning community.	93.2%	6.8%	95.4%	4.6%
You diagnose and solve technical problems in using technologies for the development of your activities.	85.1%	14.9%	89.1%	10.9%
You take care of the devices and software available to you in the school environment.	99.7%	0.3%	97.5%	2.5%
Deepening of Digital Competencies				
You evaluate the usefulness and relevance of web resources and web-based tools of your interest.	99.7%	0.3%	98.3%	1.7%
You use digital communication tools to support collaborative work among students and members of the learning community within and beyond the classroom.	97.3%	2.7%	94.1%	5.9%
You use interconnected digital devices to create a network between students and the teacher, to share digital resources and work collaboratively on different activities.	84.1%	15.9%	87.0%	13.0%
You use applications, platforms, or programs appropriate for the areas studied.	94.3%	5.7%	92.8%	7.2%
You use digital tools and resources to design your own materials and contents.	92.9%	7.1%	84.6%	15.4%
You foster a reciprocal flow of information among all members of the learning community via school communication channels.	92.6%	7.4%	78.1%	21.9%
You contribute to creating an online learning environment for lifelong learning.	86.8%	13.2%	86.7%	13.3%
You help groups and individuals to use digital devices.	91.9%	8.1%	87.1%	12.9%
You share digital resources for your social interactions and learning activities.	94.6%	5.4%	90.9%	9.1%

Table 4. Distribution of teachers and students according to the digital competencies achieved and that they can put into practice from the STEM educational experiences in which they have participated

4. Discussion

Our research study outcomes provide validation for the results of the studies presented along this paper. Varied applications of Problem-Based Learning (PBL), as discussed by Servant-Miklos (2018), Howard Samuel Barrows, and Henk G. Schmidt since the 1970s. These scholars have debated whether PBL primarily serves as a method for skill development, problem-solving, or as a conduit for understanding the underlying principles and mechanisms of problems. Additionally, historical influences on PBL development, according to Servant-Miklos, Norman and Schmidt (2019), include the Harvard University case method, Dewey's experiential learning, and Popper's recognition of problems in knowledge construction.

Like other active learning strategies, as noted by Struyf, De Loof, Boeve-de-Pauw and Van Petegem (2019), PBL is not a new concept. However, despite its longstanding presence, some educators have only recently begun to explore its implementation. The study indicates that educators who have engaged in educational experiences with a STEM approach are more inclined to incorporate active learning strategies like PBL into their teaching. Notably, these methods foster emotional and behavioral engagement among students, resulting in more effective participation.

Nevertheless, it's crucial to recognize that while STEM-focused educational approaches may attract students and enhance engagement, they do not guarantee the development of scientific vocations in all participants.

> European countries are facing potential shortage of scientific professionals in the coming years. Major reasons behind such crisis include the perception amongst students that science, technology, engineering, and math (STEM) subjects are difficult, less rewarding than some other subjects and most importantly, the ineffectiveness of traditional STEM teaching paradigm in invoking students' motivation and maintaining their interests. (Zhao, Bogusevschi & Muntean, 2018: page 2)

Although the objective of cultivating future talent in STEM fields is not always fully realized, the literature indicates that participants in educational processes with a STEM approach demonstrate development in higher-order thinking skills (Batdi, Talan & Semerci, 2019) and transversal or soft skills (Villán-Vallejo, Zitouni, García-Llamas, Fernández-Raga, Suárez-Corona & Baelo, 2022) within the cognitive domain. This is evidenced by their self-perceived mastery of 21st-century skills and the digital competencies (Manganelli, 2021) necessary to navigate emerging societal and occupational demands.

The study's findings reveal that technology and computer science are the most seamlessly integrated aspects of STEM education. However, Ellis, Wieselmann, Sivaraj, Roehrig, Dare and Ring-Whalen (2020) caution against utilizing technology for its own sake, as this approach often fails to foster meaningful conceptual learning among students. They emphasize the importance of a more precise definition and purposeful integration of technology within educational contexts. Below, we summarize the key perspectives outlined in the literature:

- Technology as Vocational Education, Industrial Arts, or the Product of Engineering
- Technology as Educational or Instructional Technology
- Technology as Coding or Computational Thinking
- Technology as Tools and Practices Used by Science, Mathematics, and Engineering Practitioners (Ellis et al., 2020: page 489).

In their investigation, Queiruga-Dios, López-Iñesta, Diez-Ojeda, Sáiz-Manzanares and Vázquez-Dorrío (2021) highlighted the pivotal role of active engagement from the educational community and external stakeholders in fostering students' readiness to confront real-world challenges. They found that this collaboration not only enables students to bridge theory with practical application but also allows external actors to gain deeper insights into the school environment, thereby facilitating meaningful impacts on educational institutions and their surrounding communities.

Regarding infrastructure, connectivity, and access to technology, the findings underscore the pressing need for enhancements in internet connectivity and the availability of essential tools such as laptops, tablets, digital boards, 3D printers, robotics kits, and electronics kits. These conclusions echo the sentiments expressed in studies like that of Arabit and Prendes (2020), which show the need for greater resources and spaces to work in STEM areas.

> Similarly, many teachers say that they do not use technological resources adequately or frequently in the classroom [...]. For their part, students indicate that they would prefer to make more frequent use of new technologies and practical activities such as experiments, which is in line with both the studies on

the subject we have collected and the recommendations we received from the European Commission on STEM. (Arabit & Prendes, 2020: page 125)

Furthermore, as Shyshkina (2018) stated, technologies enable the creation, combination, and reuse of content, services, applications, and data to organize joint activities. For this study, technologies strengthen the educational experience.

5. Conclusions

For enhanced student engagement in teaching and learning processes, the study logically suggests that Problem-Based Learning (PBL) stands out as the most used and traditional didactic strategy. This approach aims to diversify learning experiences of "Ex-Cathedra" teaching.

In alignment with the experiential nature of PBL, educators often integrate real-world contexts into their teaching methods. Students particularly identify with aspirational scenarios, such as those found in higher education institution laboratories, which serve as motivational hubs for vocational guidance.

While this study, technology and computer science emerge among teachers and students as the most integrated components of STEM experiences, there's a notable gap in their development and understanding within educational processes. Although studies frequently mention the use of digital technologies, it's crucial to broaden our understanding to include both analog and digital technologies, as well as Information and Communication Technologies (ICT), used in STEM education.

The research highlights various actions undertaken by participants during STEM processes, including planning, organization, information gathering, communication, data analysis, and report writing, among others.

In STEM approaches, active participation from the educational community, including families, and involvement from external actors such as businesses, academia, and the government, play significant roles. While teachers predominantly engage state entities and higher education students in projects, there remains untapped potential for broader multi-stakeholder participation.

Recognizing the unique characteristics of STEM approaches and leveraging previous city diagnoses prove crucial for STEM experiences in Medellín. This facilitates deeper understanding, strengthens STEM focus in educational institutions, and acknowledges progress made in other countries committed to science and technology education.

Moreover, there is discernible advancement, presenting an opportunity to further solidify Medellín as a hub for STEM disciplines. This endeavor necessitates collaborative efforts across various sectors including civil society, education, the private sector, and governmental entities. Despite educational institutions' current lack of awareness regarding their progress, as revealed in both this study and previous research, they are laying the groundwork to confront the challenges of the fourth industrial revolution. This preparation is crucial for nurturing the future scientific and technological talents among children and youth in the region.

Progress in STEM education is evident through the integration of ICT, facilitated by institutional technological provision, teacher training, and Medellín's focus on becoming an ICT hub. This progress materializes in tangible learning outcomes, including prototypes and software development.

A crucial aspect influencing the integration and advancement of STEM education within the city lies in the actors or allies directly involved. Foremost among these are the municipal administration, with Medellín designated as a Special District of Science, Technology, and Innovation, and the central government. Both entities are dedicated to fostering the development of scientific and technological skills among children and youth nationwide, evident in their educational plans and policy directives.

Various strategies, plans, and programs are deployed in this domain, spanning from initiatives supporting educators to direct engagement with students through competitions, hackathons, and camps, among other activities. Furthermore, there is limited yet significant access to resources such as 3D printers, electronics, and robotics kits. Coupled with the growing autonomy and proficiency in utilizing communication and collaboration platforms by teachers and students, these factors contribute to the holistic advancement of STEM education in the region.

Through STEM experiences, both teachers and students recognize the development of 21st-century skills and digital competencies, which in turn motivate further professional development and improvement.

In conclusion, future research should focus on longitudinal studies to assess the impact of policies, programs, and projects on STEM education in Medellín. This comprehensive approach will shed light on teaching strategies, interdisciplinary integration, skill development, and educational quality measurements. Additionally, identifying challenges and opportunities will inform future policies aimed at equipping children and young people with competencies to address contextual problems effectively.

6. Limitations

The study encountered several limitations, primarily stemming from logistical challenges in survey administration, which resulted in a longer timeframe than initially anticipated. These limitations encompassed:

- Access to institutions: Securing access to the institutions posed difficulties due to their demanding schedules. Alongside their academic commitments, these institutions juggled numerous additional obligations, constraining the time available for study participation.
- Consent acquisition from the 75 institutions: Obtaining official authorization to conduct surveys across all 75 institutions presented a significant challenge. Consequently, a direct invitation was extended through the Vivero del Software of the Department of Education in Medellín.
- Implementation of a self-directed digital survey: This required ensuring that institutions allocated space and time for both teachers and students to complete the survey. Additionally, access to computers was required for participants to complete the survey in groups, facilitating maximum respondent participation.
- Budgetary management: The project’s co-financing by multiple institutions, both public and private, introduced complexities as each managed resources independently. This added a layer of intricacy to the project management process.

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Declaration of Conflicting Interests

The authors declare that there are no potential conflicts of interest concerning the research, authorship, and/or publication of this article.

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References

Alharahsheh, H.H., & Pius, A. (2020). A review of key paradigms: Positivism VS interpretivism. *Global Academic Global Academic Journal of Humanities and Social Sciences,* 2(3), 39-43. https://doi.org/10.36348/gajhss.2020.v02i03.001

Allard, S., & Cortez, E. (2013). *Aspectos fundamentales sobre la Educación STEM (enfoque interdisciplinario de ciencia, tecnología, ingeniería y matemáticas/medicina): Lecciones aprendidas en la Universidad de Tennessee, USA.* Paper presented at IFLA WLIC 2013 - Singapore - Future Libraries: Infinite Possibilities in Session 197. Science and Technology Libraries. Available at: https://library.ifla.org/id/eprint/170

Anabousy, A. & Daher, W. (2022). Pre-Service teachers' design of STEAM learning units: STEAM capabilities' analysis. *Journal of Technology and Science Education,* 12(2), 529-546. https://doi.org/10.3926/jotse.1621

Ángel-Uribe, I.C., Escobar-Ortiz, J.M., López-Molina, G., Ramírez-Hoyos, D.M., Uribe-Zapata, A., Vera-Muñoz, A.S. et al. (2024). *Explorando el enfoque STEM: reflexiones desde diversos contextos.* Editorial ITM. https://doi.org/10.22430/9789585122857

Arabit, J., & Prendes, M.P. (2020). Metodologías y Tecnologías para enseñar STEM en Educación Primaria: análisis de necesidades. *Pixel-Bit,* 57, 107-128. https://doi.org/10.12795/pixelbit.2020.i57.04

Arizona STEM Network & The Maricopa County Educational Services Agency (2017). *The Stem Immersion Guide.* Scottsdale. Science Foundation Arizona.

Batdi, V., Talan, T., & Semerci, C. (2019). Meta-analytic and meta-thematic analysis of STEM education. *International Journal of Education in Mathematics, Science and Technology,* 7(4), 382-399. Available at: https://www.ijemst.com/index.php/ijemst

Beard, C. (2018). Dewey in the World of Experiential Education. In Mandell, A., & Coulter, X. (Eds.), *New Directions for adult and continuing education* (27-37). Wiley Online Library. https://doi.org/10.1002/ace.20276

Bosch, H., Di Blasi, M., Pelem, M., Bergero, M., Carvajal, L., & Geromini, N. (2011). Nuevo paradigma pedagógico para enseñanza de ciencias y matemática. *Avances en Ciencias e Ingeniería,* 2(3), 131-140. Available at: https://dialnet.unirioja.es/servlet/articulo?codigo=3752199

Buitrago, L., Laverde, G., Amaya, L., & Hernández, S. (2022). Pensamiento computacional y educación STEM: reflexiones para una educación inclusiva desde las prácticas pedagógicas. *Panorama,* 16(30), 1-24. https://doi.org/10.15765/pnrm.v16i30.3134

Cano, L.M., & Ángel-Uribe, I.C (2020). *Medellín Territorio STEM+H. Un diagnóstico de la Secretaría de Educación de Medellín sobre el desarrollo del enfoque en las instituciones educativas de la ciudad.* Editorial Universidad Pontificia Bolivariana. https://doi.org/10.18566/978-958-764-837-9

Chacko, P., Appelbaum, S., Kim, H., Zhao, J., & Montclare, J. (2015). Integrating technology in STEM education. *Journal of Technology and Science Education,* 5(1), 5-14. https://doi.org/10.3926/jotse.124

Cheng, J., & Feng, B. (2016). A just-in-time model for e-teaching and e-learning STEM in virtual classrooms. *Journal of Information Systems Technology & Planning,* 8(19), 83-94.

Ching-Chiang, L., & Fernández-Cárdenas, J. (2019). Analysing dialogue in STEM classrooms in Ecuador: A dual socioeconomic context in a high school. *Journal of New Approaches in Educational Research,* 9(2), 194-215. https://doi.org/10.7821/naer.2020.7.529

Coello, S., Rodríguez, B., González, Y., & Hidalgo, J. (2021). Habilidades profesionales STEM e industria 4.0 para estudiantes de Física Aplicada en proyectos disciplinarios I+D+i. *Latin-American Journal of Physics Education,* 15(3), 3308-3317. Available at: https://dialnet.unirioja.es/servlet/articulo?codigo=8358272

Daugherty, M., Carter, V., & Sumner, A. (2021). Standards for technological and engineering literacy and STEM education. *Technology and Engineering Teacher,* 8(5), 32-37. Available at: https://par.nsf.gov/servlets/purl/10210627

Diamantopoulos, N., Brami, A., & Spanos, I. (2018). Flipped classroom STEM Teaching: An innovative practice of technologically supported teaching of physics. *Annals. Computer Science Series,* 16(3), 16-20. Available at: http://anale-informatica.tibiscus.ro/download/lucrari/16-3-02-Diamantopoulos.pdf

Díaz-Barriga, F., & Hernández, G. (2002). *Estrategias docentes para un aprendizaje significativo: una interpretación constructivista.* Mc Graw Hill.

Domínguez, P., Oliveros, M., Coronado, M., & Valdez, B. (2019). Retos de ingeniería: enfoque educativo STEM+A en la revolución industrial 4.0. *Innovación Educativa,* 19(80), 15-32. Available at: https://www.scielo.org.mx/scielo.php?script=sci_arttext&pid=S1665-26732019000200015

Duglio, I. (2016). Educación STEM. *Jornadas de formación de la Oportunidad.* Available at: http://depquimica.cfe.edu.uy/images/pdf/STEM/EducacionSTEMRivera.pdf

ECLAC (2013). *La integración de las tecnologías digitales en las escuelas de América Latina y el Caribe. Una mirada multidimensional.* Naciones Unidas y @LIS. Available at: https://repositorio.cepal.org/bitstream/handle/11362/21681/S2013023_es.pdf

Ellis, J., Wieselmann, J., Sivaraj, R., Roehrig, G., Dare, E., & Ring-Whalen, E. (2020). Toward a productive definition of technology in science and STEM education. *Cite Journal. Contemporary Issues in Technology and Teacher Education,* 20(3), 472-496. Available at: https://citejournal.org/publication/volume-20/issue-3-20/

Esquer, M., & Fernández, K. (2020). La práctica docente en áreas STEM: mapeo sistemático de la literatura. *Revista Educacion,* 45(1), 1-14. https://doi.org/10.15517/revedu.v45i1.42809

Euefueno, W. (2019). Project-/problem-based learning in STEM: impacts on student learning. *Technology and engineering teacher,* 78(8), 8-12. Available at: https://digitalcommons.odu.edu/cgi/viewcontent.cgi?article=1084&context=stemps_fac_pubs

Fauber, D., & Becker-Blau, R. (2020). The #FIRST in family initiative: supporting communities and engaging children in STEM learning. *Technology and eNgineering Teacher,* 80, 14-19. Available at: https://www.iteea.org/Publications/Journals/53685/179812.aspx

Fernández, J., Zúñiga, M., Rosas, M., & Guerrero, R. (2018). Experiences in learning problem-solving through. Computational Thinking. *Journal of Computer Science & Technology,* 18(2), 136-142. https://doi.org/10.24215/16666038.18.e15

Ferrada, C., Diaz-Levicoy, D., & Puraivan, E. (2022). Aula en un ambiente STEM: una oportunidad para la innovación. *Revista DIM: Didáctica, Innovación y Multimedia,* 40, 1-12. Available at: https://www.raco.cat/index.php/DIM/article/view/402812

Friedensen, R.E., Kimball, E., Vaccaro, A., Miller, R.A., & Forester, R. (2021). Queer science: Temporality and futurity for queer students in STEM. *Time & Society,* 30(3), 332-354. https://doi.org/10.1177/0961463X211008138

Fundación Omar Dengo (2014). *Competencias del siglo XXI. Guía práctica para promover su aprendizaje y evaluación.* Fundación Omar Dengo. Available at: https://www.viaeducacion.org/downloads/ap/ehd/competencias_siglo_xxi.pdf

García-Tort, E. (2024). Las STEM en la Educación Secundaria Obligatoria: un análisis comparativo. *Atenas,* 62, 1-11. Available at: https://hdl.handle.net/10550/96593

Grau, S., Reig, R., Puig, A., López, M., & Rodríguez, I. (2015). Games4Learning: How to integrate serious games to personalized learning itineraries? *10th Iberian Conference on Information Systems and Technologies, (CISTI).* https://doi.org/10.1109/CISTI.2015.7170612

Guanotuña-Balladares, G.E., Pujos-Basantes, A.A., Oñate-Pazmiño, M.F., Ponce-Jiménez, M.A., Carrillo-Llumitaxi, E.P., Delgado-Yar, N.P. et al. (2024). Adaptación de la Metodología STEM-STEAM en la educación pospandemia: un enfoque integral para la recuperación académica. *Revista InveCom,* 4(2), 1-11. https://doi.org/10.61384/r.c.a..v4i2.360

Harris, B., Dassopoulos, A., Sahl, D., & Starostina, A. (2021). Increasing investment in STEM education for females: policy considerations. *UNLV Gaming Research & Review Journal,* 25(1), 1-11. Available at: https://digitalscholarship.unlv.edu/grrj/vol25/iss1/1/

Hutton, C., & Mis, T. (2022). Best-practices in STEM education in a virtual learning environment. *Technology and Engineering Teacher,* 81(7), 24-29. Available at: https://eric.ed.gov/?id=EJ1338998

Johnson, C., Moore, T., & Peters-Burton, E. (2015). *STEM road map: A framework for integrated STEM education.* Routledge. https://doi.org/10.4324/9781315753157

Jolly, A. (2012). *Real-World STEM Problems.* Middle Web. All about the middle grades. Available at: https://www.middleweb.com/5003/real-world-stem-problems/

Jolly, A. (2014). *Six Characteristics of a Great STEM Lesson.* Education Week. Available at: https://www.edweek.org/teaching-learning/opinion-six-characteristics-of-a-great-stem-lesson/2014/06

Jolly, A. (2016). Begin STEM Planning with a 5-Point Checkup. STEM by Design: A Resource Site for Bringing STEM Alive in Your Classroom. https://doi.org/10.4324/9781315679976

Kefalis, C., & Drigas, A. (2019). Web based and online applications in STEM education. *International Journal of Engineering Pedagogy (iJEP),* 9(4), 76-85. https://doi.org/10.3991/ijep.v9i4.10691

Kelley, T., & Knowles, J. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education,* 3(11), 1-11. https://doi.org/10.1186/s40594-016-0046-z

Kennedy, T., & Odell, M. (2014). Engaging students in STEM education. *Science Education International,* 25(3), 246-258. Available at: https://eric.ed.gov/?id=EJ1044508

Kersanszki, T., & Nadai, L. (2020). The position of STEM higher education courses in the labor market. *International Journal of Engineering Pedagogy (iJEP),* 10(5), 62-76. https://doi.org/10.3991/ijep.v10i5.13905

Lancaster, C., & Jade-Xu, Y. (2017). Challenges and supports for African American STEM student persistence: A case study at a racially diverse four-year institution. *The Journal of Negro Education,* 86(2), 176-189. https://doi.org/10.7709/jnegroeducation.86.2.0176

Langie, G., & Pinxten, M. (2018). The Transition to STEM Higher Education: Policy Recommendations. Conclusions of the readySTEMgo-Project. *International Journal of Engineering Pedagogy (iJEP),* 8(2), 10-13. https://doi.org/10.3991/ijep.v8i2.8286

Ler, D., & Wong, G. (2016). Jurong Junior College's (JJC) STEM Nexus Programme. *Innovation,* 15(1), 92-95. Available at: http://www.innovationmagazine.com/volumes/v15n1/contents.html

Lewis, D.C. (2015). Increasing diversity and inclusion for women in STEM. DOCEAMUS. *Notices of the American Mathematical Society,* 62(8), 920-922. https://doi.org/10.1090/noti1272

López-Molina, G., Ramírez-Hoyos, D.M., Angel-Uribe, I.C., Escobar-Ortiz, J.M., Uribe-Zapata, A., Cano-Vásquez, L.M. et al. (n.d.). *Previos para una educación con enfoque STEM.* Fondo Editorial ITM.

Love, T.S., & Roy, K. R. (2018). Converting classrooms to makerspaces or STEM labs: design and safety considerations. *Technology and Engineering Teacher,* 78(1), 34-36. https://eric.ed.gov/?id=ej1190258

Manganelli, S. (2021). Aportes de las herramientas digitales a STEM, durante la investigación científica, para fomentar el desarrollo de competencias científicas, tecnológicas y digitales. In *XXVII Congreso Argentino de Ciencias de la Computación (CACIC)* (94-103). Available at: https://cacic2021.unsa.edu.ar/wp-content/uploads/2021/11/LIBRO-DE-ACTAS-CACIC-2021-SALTA.pdf

Marín-Arrieta, P. (2024). *Impacto de estrategias públicas y privadas para la adopción de carreras STEM en estudiantes y egresados del Gran Área Metropolitana costarricense.* Master's tesis, Universidad Latinoamericana de Ciencia y Tecnología. Available at: https://hdl.handle.net/20.500.14230/11000

Maynard, C., García, J., Lucietto, A., Hutzel, W., & Newell, B. (2021) Experiential Learning in the Energy Based Classroom. *International Journal of Engineering Pedagogy,* 11(6), 4-26. https://doi.org/10.3991/ijep.v11i6.16539

Mayor's Office of Medellín (2020). *Plan de Desarrollo Medellín Futuro 2020 - 2023.* Mayor's Office of Medellín. Available at: https://www.Medellín.gov.co/irj/go/km/docs/pccdesign/Medellín/Temas/PlanDesarrollo/Publicaciones/Shared%20Content/Documentos/2020/DocumentoFinal_PlanDesarrolloMedellín2020-2023_MedellínFuturo.pdf

Mayor's Office of Medellín (2022). *Congreso aprobó la Ley orgánica que reglamenta a Medellín como Distrito de Ciencia, Tecnología e Innovación.* Available at: https://www.Medellín.gov.co/es/sala-de-prensa/noticias/congreso-aprobo-la-ley-organica-que-reglamenta-a-Medellín-como-distrito-de-ciencia-tecnologia-e-innovacion/

Mcdonald, C.V. (2016). STEM Education: A review of the contribution of the disciplines of science, technology, engineering and mathematics. *Science Education International,* 27(4), 530-569. Available at: http://www.icaseonline.net/sei/december2016/p4.pdf

Méndez, A., & Alfaro, J. (2020). Playing RoboSoccer with machine learning: A learning and teaching experience based on STEM. Proceedings CISTI. *Iberian Conference on Information Systems & Technologies.* https://doi.org/10.23919/CISTI49556.2020.9141102

Moore, T., Roehrig, G., Wang, H., & Park, M.S. (2012). Is adding the e enough? Investigating the impact of k-12 engineering standards on the implementation of STEM Integration. *School Science and Mathematics,* 112(1), 31-44. https://doi.org/10.1111/j.1949-8594.2011.00112.x

Mova & Mayor's Office of Medellín (2020). *Marco Ser+STEM. Estamos transformando la educación en Medellín.* Major's Office of Medellín.

Parker, J., & Lazaros, E. (2014). Teaching 21st century skills and STEM concepts in the elementary classroom. *Children's Technology and Engineering,* 18(4), 24-27.

Peterson, B. (2017). Engaging parents in STEM education. *Children's Technology and Engineering,* 22(1), 18-21. Available at: https://www.iteea.org/News/282/119130.aspx?source=generalSearch

Queiruga-Dios, M.Á., López-Iñesta, E., Diez-Ojeda, M., Sáiz-Manzanares, M.C., & Vázquez-Dorrío, J.B. (2021). Implementation of a STEAM project in compulsory secondary education that creates connections with the environment. *Journal for the Study of Education and Development,* 44(4), 871-908. https://doi.org/10.1080/02103702.2021.1925475

Ramos-Lizcano, C., Ángel-Uribe, I.C., López-Molina, G., & Cano-Ruiz, Y.M. (2022). Elementos centrales de experiencias educativas con enfoque STEM. *Revista Científica,* 45(3), 345-357. https://doi.org/10.14483/23448350.19298

Reinholz, D.L., White, I., & Andrews, T. (2021). Change theory in STEM higher education: a systematic review. *International Journal of STEM Education,* 8(37), 1-22. https://doi.org/10.1186/s40594-021-00291-2

Ribble, D. (2022). Ahead of his time: Joseph Grinnell, natural history, and inclusion and equity in STEM. *Therya,* 13(1), 99-102. https://doi.org/10.12933/therya-22-1104

Rico, A.D. & Cogollo, C.E. (2019). *La sistematización de experiencias. Apuesta investigativa para innovar y transformar escenarios educativos y pedagógicos.* Ediciones USTA. Available at: https://repository.usta.edu.co/bitstream/handle/11634/27774/Primerapartedelosrelatoscapitulo1aspectoscriticos2020alejandrarico.pdf

Roberts, T. (2021). STEL standards and integrating into the elementary STEM community. *The Elementary STEM Journal,* 25(3), 1-2. Available at: https://www.iteea.org/Publications/Journals/ESCJournal/ESJ-March21.aspx

Roberts, T., Maiorca, C., & Chapman, P. (2019). Equitably engaging all students in STEM. *The Elementary STEM Journal,* 23(4). 30-33. Available at: https://www.iteea.org/Publications/Journals/ESCJournal/ESJ-May2019/153981.aspx#publicationContent

Rozo, G., Fuentes, J., Ruiz, M., & Patiño, E. (2020). M*odelo de apropiación de Medellín Digital en Instituciones Educativas Públicas de Medellín desarrollado entre el 2007 y 2012.* Available at: https://recursos.educoas.org/sites/default/files/VE13.406.pdf

Salinas, J. (2004). Innovación docente y uso de las TIC en la enseñanza universitaria. *Revista Universidad y Sociedad del Conocimiento,* 1(1), 1-16. https://doi.org/10.7238/rusc.v1i1.228

Sanabria-Rangel, P.E., & Ospina-Díaz, M.R. (2023). Enfoque STEAM en la educación superior colombiana frente a la cuarta revolución. *Educación Y Humanismo,* 25(45). https://doi.org/10.17081/eduhum.25.45.6152

Sanders, M. (2009). STEM, STEM Education, STEMmania. *The Technology Teacher,* 64(4), 20-26. Available at: https://vtechworks.lib.vt.edu/bitstream/handle/10919/51616/STEMmania.pdf?sequence

Servant-Miklos, V.F.C. (2018). Problem solving skills versus knowledge acquisition: the historical dispute that split problem-based learning into two camps. *Advances in Health Sciences Education,* 24, 619-635. https://doi.org/10.1007/s10459-018-9835-0

Servant-Miklos, V.F.C., Norman, G.R. & Schmidt, H.G. (2019). A Short Intellectual History of Problem-Based Learning. In Mahnaz, M., Woei, H., & Dabbagh, N. (Ed.), *The Wiley Handbook of Problem-Based Learning* (3-24). Wiley Blackwell. https://doi.org/10.1002/9781119173243.ch1

Shui, W., & Cheng, G. (2019). Integrating drone technology in STEM education: A case study to assess teachers' readiness and training needs. *Issues in Informing Science + Information Technology,* 16, 61-70. https://doi.org/10.28945/4288

Shyshkina, M. (2018). The problems of personnel training for STEM education in the modern innovative learning and research environment. AREdu 2018. *International Workshop on Augmented Reality in Education.* Kryvyi Rih, Ukraine. Available at: https://ceur-ws.org/Vol-2257/

Sondergeld, T. (2013). Closing the Gap Between STEM Teacher Classroom Assessment Expectations and Skills. *SSM Journal,* 114(4), 151-153. https://doi.org/10.1111/ssm.12069

Struyf, A., De Loof, H., Boeve-de-Pauw, J., & Van Petegem, P. (2019). Students' engagement in different STEM learning environments: integrated STEM education as promising practice? *International Journal of Science Education,* 41(10), 1387-1407. https://doi.org/10.1080/09500693.2019.1607983

Torrado, M. (2004). Estudios de Encuesta. In Bisquerra, R. (Coord.), *Metodología de la investigación educativa* (231-257). La Muralla.

Trung, T., & Hong, L. (2019). Integrating art with STEM education-STEM education in Vietnam high schools. *Anale. Seria Informatică,* 17(1), 203-213. Available at: http://anale-informatica.tibiscus.ro/download/lucrari/17-1-27-TranTrung.pdf

Tsupros, N., Hallinen, J., & Shoop, R. (2009). *Intermediate Unit 1. En Report of a project to identify the missing components.* Pennsylvania.

UNESCO (2019). *Marco de competencias de los docentes en materia de TIC. Versión 3.* UNESCO. Available at: https://eduteka.icesi.edu.co/pdfdir/unesco-competencias-tic-docentes-version-3-2019.pdf

UNICEF (2014). *Las políticas TIC en los sistemas educativos de América Latina. Caso Colombia.* UNICEF. Available at: https://en.unesco.org/icted/sites/default/files/2019-04/colombia_web.pdf

Verma, A., Dickerson, D., & McKinney, S. (2011). Engaging Students in STEM Careers with Project-Based Learning-MarineTech Project. *Technology and Engineering Teacher,* 71(1), 25-31. Available at: https://www.proquest.com/openview/836bcfb92a476466a8eece2c883faab4/1?pq-origsite=gscholar&cbl=34845

Villán-Vallejo, A., Zitouni, A., García-Llamas, P., Fernández-Raga, M., Suárez-Corona, A., & Baelo, R. (2022). Soft Skills and STEM Education: Vision of the European University EURECA-PRO. *BHM Berg-und Hüttenmännische Monatshefte,* 167(10), 485-488. https://doi.org/10.1007/s00501-022-01275-7

Welling, J., & Wright, G. (2018) Teaching engineering design through paper rockets. *Technology and Engineering Teacher,* 77(8), 18-21. Available at: https://eric.ed.gov/?id=EJ1177688

West, S., & Motz, L. (2017). Safer STEM and CTE classroom/laboratory facilities design: general guidelines. *Technology and Engineering Teacher,* 76(5), 20-22. Available at: https://www.iteea.org/News/282/106447.aspx?source=generalSearch

Young, H., Carter, V., & Bengtson, E. (2020). An innovative setting for STEM education. *The Elementary STEM Journal,* 24(3), 11-15. Available at: https://www.iteea.org/Publications/Journals/ESCJournal/ESJ-March20.aspx

Zaher, A., & Damaj, I. (2018). Extending STEM Education to Engineering Programs at the Undergraduate College Level. *International Journal of Engineering Pedagogy (iJEP),* 8(3), 4-16. https://doi.org/10.3991/ijep.v8i3.8402

Zhao, D., Bogusevschi, D., & Muntean, G.M. (2018). Improving Future STEM Education with Innovative Learning Management System and Technology-Enhanced Learning Materials. *NEWTON Project and Large-Scale Pilots. International Conference on Engaging Pedagogy (ICEP).* Dublin City University, Dublin, Ireland. Available at: http://www.newtonproject.eu/wp-content/uploads/2019/08/Dan_Diana_Gabriel_ICEP-paper.pdf

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