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ICT-Mediated STEM for the Inclusive Education of Migrants and Refugees Children

Juan Sebastián Sánchez-Gómez, Universidad El Bosque

Doctoral student of PhD in Industrial and Systems Engineering at Universidad de los Andes (Colombia).

Maria Catalina Ramirez
Andrea Herrera, Universidad de los Andes, Columbia

ICT-mediated STEM for the inclusive education of migrants and refugees' children

Juan Sebastián Sánchez-Gómez[1,2,3], María Catalina Ramirez Cajiao[2] y Andrea Herrera[3]
[1] Facultad de Ingeniería, Universidad El Bosque
[2] Departamento de Ingeniería Industrial, Universidad de los Andes
[3] Departamento de Ingeniería de Sistemas y Computación, Universidad de los Andes

Abstract

Science, Technology, Engineering, and Mathematics (STEM) is an approach that integrates science and mathematics education through the development of scientific practices, technology, engineering design, and mathematical analysis. Although governments in North American and European countries have invested in promoting the study of STEM disciplines, educational programs for migrants have been offered for adults, and very few programs for children, which are invisible, downplaying the effects of migration on the educational process of children. Educational interventions are needed at early ages, focusing on the funds of knowledge from the children's informal learning during their migratory trajectories, such as the United States and Israel, as host countries that have historically reaped the benefits of immigration. Inclusive education requires ICTs to overcome the social, economic, and cultural barriers presented by migrant children. However, transnational education studies focus on the effects of migration on children's identity and academic success, but there is a gap in the literature on empirical studies on the role of ICT-mediated STEM education in migrant and refugee children.

For this reason, a systematic literature review was developed in Web of Science, which aims to close the gap in the literature and show that STEM education develops skills that allow migrant families access to economic and social benefits and promote social innovation processes in destination countries. The search algorithm that linked STEM education research and its relationship with ICT, in conjunction with the target population of migrant and refugee children. This algorithm was refined for publications written in Spanish and English between 2000 and 2023 yielding 70445 publications. These publications were evaluated by 5 criteria: the prestige of the journal/publisher and author, consistency, thematic appropriateness, and relevance of the results.

This resulted in 338 publications that were classified into contribution levels according to the score obtained in the evaluation criteria. Finally, 48 publications were selected for their high level of contribution to 8 major themes that were developed i) the disciplines of STEM education, ii) the delimited definition of STEM education, iii) the benefits of STEM education, iv) STEM learning for migrant and refugee children, v) Computational thinking at K-12 STEM education, vi) STEM education for innovation, vii) STEM integration cases, and viii) STEM in the inclusive learning spaces. It is concluded that ICT-mediated STEM promotes inclusive learning spaces in which diversity is valued and quality education for all is guaranteed. While it is demystified that migrants and refugees do not have electronic devices, children should be guaranteed full access to the ICT-mediated learning environment during their migrant journey. Finally, it is proposed to deepen the literature on the development of computational thinking skills in children, as it is considered the basis of STEM disciplines for the design of activities that integrate these disciplines and are adapted to the educational needs of migrant and refugee children.

Introduction

Migrant and refugee do not have the same meaning, so it is necessary to have a notion of each. Being a migrant is a social, historical, and political construction determined by each State within the framework of its State policies, which are aligned with international law. A migrant is defined by the International Organization for Migration as someone who has transited outside his or her residence, either through the internal border of his or her country or through international borders between countries, regardless of their migratory status and the duration of their stay in the countries of transit or destination [1].

While being a refugee is a legal category established by the United Nations in 1979, for people who require international protection from the UN through the High Commissioner for Refugees (UNHCR), regardless of the membership and ratification of the host country of the 1951 Convention and the 1967 Protocol [2]. Thus, a refugee is defined by the 1951 Convention relating to the Status of Refugees as a person with a well-founded fear of persecution on account of race, religion, nationality, membership in a particular social group or political opinion, is outside the country of which is a national, is unwilling to be protected by that country and is unwilling to return [3].

These definitions show that migration is understood as a security problem, whose public policies depend on national and international authorities, which decide who is protected and declared as a refugee [4]. In general, migrants apply for asylum to be protected by the host States, but from, during, and until the end of the asylum process, they are migrants. Within this population, migrant children are the most vulnerable, as they present a double vulnerability, a first vulnerability related to their status as migrants in a situation of lesser power compared to residents of transit or destination countries, and a second vulnerability associated with their status as children, which does not allow them to defend their rights.

In this migration context, transit and destination countries miss out on the educational potential of migrant children, who remain out of school during their migratory trajectory, but demonstrate informal learning, known as funds of knowledge [5]. In addition to funds of knowledge, children develop cultural and digital competencies and resources through interaction with new communities during their migration journey. These knowledge, skills, and resources can be incorporated into the classroom from a STEM approach to improve their educational outcomes and generate a more inclusive classroom [6].

The term STEM was first used in 1990 by the National Science Foundations in the United States as an acronym for policies, projects, and programs in the disciplines of Science, Technology, Engineering, and Mathematics (STEM). STEM programs and projects have been developed for privileged populations that have had access to the best schools and universities in the world, so their benefits for vulnerable populations such as migrants and refugees have not been studied.

However, STEM Education presents barriers and myths that discourage the interest of children and adolescents in these disciplines [7]. This context makes necessary an educational intervention at early ages so that children become interested in STEM disciplines [8]. These early educational interventions could be expanded to migrant and refugee children to enhance the benefits of STEM education for these children during their migration journey in each host country, taking advantage of the fact that STEM education aims to develop skills that allow access to economic and social benefits [9], through learning science by doing science [10].

For this reason, a systematic literature review is proposed to identify and evaluate the validity of the most important studies that answer the research question [11] and synthesize relevant information on STEM education for migrant and refugee children [12]. This review answers the research question about what is the importance of STEM education with ICT in the inclusive learning spaces of migrant children? The results obtained from the systematic review were classified into 8 major themes, such as i) the disciplines of STEM education, ii) the delimited definition of STEM education, iii) the benefits of STEM education, iv) STEM learning for migrant and refugee children, v) Computational thinking at K-12 STEM education, vi) STEM education for innovation, vii) STEM integration cases, and viii) STEM in the inclusive learning spaces.

Background

The migration laws condition the entry, exit, activities, and time of stay in the country, as state mechanisms to protect its borders. Enforcement of immigration laws is complex and costly, discouraging regular migration and promoting irregular migration. The exercise of territorial sovereignty has created bureaucracy in the consulates of immigration states that are popular in countries of emigration, as well as the emergence of an industry of legal and illegal migration service providers, which together made migration a national security problem [13], pressuring governments to limit immigration and forcing them to allocate greater economic resources to strengthen the migration regime [14].

Therefore, migrants from the Global South are perceived as a threat to the national security of the Global North [15]. This unfounded perception is complemented by beliefs about the causes of migration, mainly forced migration due to a lack of economic development that forces migration to developed countries [16]. However, the UNDP has reported that most migrants are not poor, and that poor countries are not emigrant countries [17]. On the contrary, economic development increases migration, because of the skills that migrants develop in destination countries that they then share in their countries of origin [18].

Some migrant-receiving countries that represent successful cases of immigration benefits are the United States and Israel. In the case of the United States, illegal immigration has a significant and positive impact on its economy, although the fiscal costs are still unquantifiable because there is a disproportionate allocation of resources between the federal and state governments [19]. Likewise, the United States has received the migration of foreign scientists for their high level of education and that of their children [20]. Foreign scientists and engineers hold important positions in U.S. universities, laboratories, and scientific industries [21]. Finally, one in four U.S. technology companies were founded between 1995 and 2005 by a foreign entrepreneur [22].

In the case of Israel, the unrestricted mass migration of Jews from the former Soviet Union (FSU) in 1990 has been unique in the world for its benefits. Jewish immigrants from the FSU increased Israel's population by 20%, created their political parties to become a coalition government, promoted greater economic freedom, and moved the country away from socialism [23]. Clark et al. demonstrated with their empirical analysis of different countries that immigrant flows were related to improvements in economic institutions, which contradicts the belief that unrestricted migration produces institutional deterioration [24].

Methodology

Following the methodology of [25], a systematic literature review was conducted in 3 phases: planning, development, and reporting (see Table 1).

Phases	Activities
Planning	Identify the needs of the review
	Formulate the research question.
	Define the review protocol.
Development	Identify relevant research.
	Extract and synthesize relevant data.
Report	Writing the full review report.

Table 1. Activities of each phase of the review. Adapted from [26].

In the planning phase, we by formulating the research question that guides the systematic literature review, as well as defining the review protocol. In this sense, the research question is what is the importance of STEM education with ICT in the inclusive learning spaces of migrant children?

For this purpose, 13 keywords were identified as one of the search criteria (shown in Table 2) in publications in Spanish or English.

Criteria	Description
Languages	Spanish and English
Keywords	#1: Information and Communication Technology #2: Education #3: role of ICT #4: STEM education #6: Migrant children #7: Migrant child #8: migrant students #9: migrant child #10: refugee children #11: Refugee child #12: Child #13: Children
Types of publications	Refereed articles, conference papers, and books
Databases consulted	Web of Science

Table 2. Search Criteria.

Once the search criteria were defined, evaluation criteria were also proposed (see Table 3), to analyze the relevance of each publication according to its level of contribution, with 0 being a low contribution, 1 a medium contribution, and 2 a high contribution. All the criteria are assessed at the researcher's discretion, except for the criteria of the journal's prestige and the authors' prestige.

Regarding the prestige of the journal, journals indexed in the Q1 and Q2 quartiles have a high contribution, and journals indexed in the Q3 and Q4 quartiles have a medium contribution, while non-indexed journals have a low contribution. The prestige of the authors is assessed according to the h-index of the first author of the article, being an h-index of 10 a high contribution, 5 to 9 a medium contribution, and less than or equal to 4 a low contribution.

Criteria	**Contribution**	**Description**
Journal/organization	0-2 points	The prestige of the journal/organization
Authors	0-2 points	Author prestige (h-index)
Consistency	0-2 points	Consistency of the abstract
Adequacy	0-2 points	Thematic alignment with this research.
Results	0-2 points	The usefulness of the results of this research
Total	10 points	

Table 3. Criteria for assessing relevance. Adapted from [26].

Results

The last phase of the systematic literature review is reporting the results. The search algorithm resulting from searches #5 and #14 on Web of Science initially showed 360115 publications. This algorithm was refined for 70445 publications in educational research written in Spanish or English from 2000 to 2023 (see Figure 1).

Figure 1. Initial results in Web of Science.

However, 70445 publications are difficult to process, so the criteria for assessing relevance were applied (see Table 3). The publications were selected according to the evaluation of their level of contribution to this research (see Table 4), discardable (0-3 points), low (4 to 6 points), medium (7 to 8 points), and high contribution (9 to 10 points).

Contribution	**Quantity**	**Percentage**
Discarded	125	37%
Low	104	31%
Median	61	18%
High	48	14%
Total	338	100%

Table 4. The final valuation of publications. Adapted from [26].

Considering the above, only publications with a high contribution rating, i.e., with a score of 9 to 10 points, were selected. The most relevant publications were 338, which allowed the construction of a conceptual map (see Figure 2) of 8 themes that will be presented below: i) the disciplines of STEM education, ii) the delimited definition of STEM education, iii) the benefits of STEM education, iv) STEM learning for migrant and refugee children, v) Computational thinking at K-12 STEM education, vi) STEM education for innovation, vii) STEM integration cases, and viii) STEM in the inclusive learning spaces.

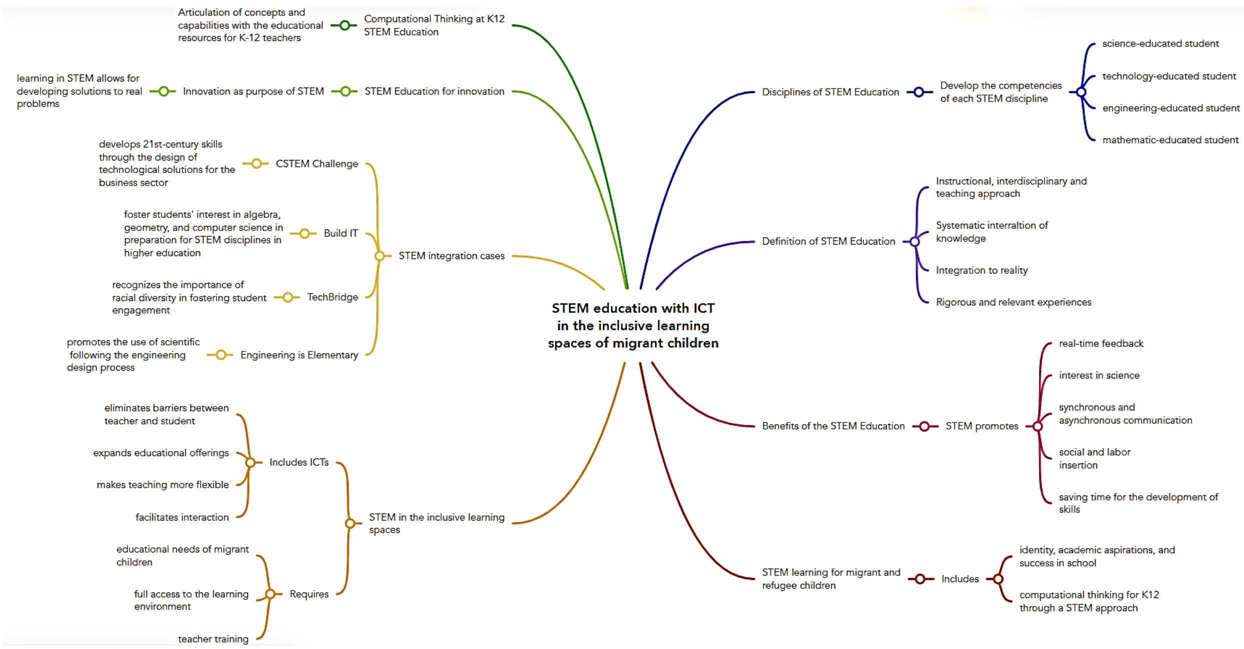

Figure 2. Conceptual map.

The disciplines of STEM education

STEM education is born from the integration of four disciplines: science, technology, engineering, and mathematics. According to the U.S. National Research Council [27]., each discipline separately: i) science from its scientific theories supports the engineering design process, ii) technology is a product of science and engineering, and in turn, technological tools are used in these, iii) engineering uses scientific and mathematical foundations, as well as technological tools, and v) mathematics is used in science, engineering, and technology. However, the individual focus of each discipline allows us to understand the complexities of its theoretical conceptualization and teaching and learning methodologies. In this sense, a student instructed in STEM should develop the competencies of each of the four disciplines [28] as explained below.

First, the science-educated student: i) will have the scientific concepts and theories, ii) the ability to connect them between the sciences and between other disciplines, iii) the ability to experiment with solutions to real problems using engineering concepts [29], and iv) the ability to reason and argue based on evidence [30].

Second, the technology-educated student: i) will have clarity about current, developing, and future technologies, ii) be able to recognize the advantages, disadvantages, and risks of technologies, and iii) know about the infrastructure that manufactures, operates, and maintains them [29].

Third, the engineering-educated student: i) will be able to identify, decompose and solve problems, ii) will be able to recognize the relationship between the sciences, arts, and engineering, iii) will be able to identify the impacts generated by engineering artifacts [29] and iv) create and test solutions following the engineering design process [30].

Finally, the mathematic-educated student: (i) will be able to explain and express mathematical ideas, and (ii) will be able to make mathematically informed judgments [29]. However, it is important to recognize a delimited definition of STEM education, which allows us to recognize that it is not limited to the instruction of each discipline but integrates them and connects them with other areas of knowledge [28].

Delimited definition of STEM education

Science, Technology, Engineering, and Mathematics (STEM) education is an instructional, interdisciplinary, and teaching approach. First, it is an instructional approach that integrates science and mathematics education through the development of scientific inquiry practices, technology and engineering design, mathematical analysis, and 21st-century skills [31]. Second, is an interdisciplinary approach to learning, which allows eliminating the traditional science, technology, engineering, and mathematics, to integrate them with real and relevant experiences [29]. Third, is a teaching approach within an authentic context to connect STEM disciplines to enhance the learning experience [32].

The general definition of STEM education can be interpreted into 4 main concepts: (i) the interdisciplinary approach to learning, understood as a deep integration that allows connecting the theoretical foundations of each discipline; (ii) the elimination of the barriers of the four disciplines, i.e. transforming the traditional vision of learning from isolated concepts disconnected from reality to a new form of the systematic interrelation of knowledge; iii) integration to reality, which means the conceptual connection of the four disciplines with real-life experiences; and iv) rigorous and relevant experiences for students, which implies engaging the student with the challenge of applying the holistic of the four disciplines to their daily problems [28].

However, not all educational initiatives are STEM, so it is common to find educational institutions that call themselves STEM, only to present a promise of value that includes a STEM curriculum design and STEM educational resources, which are not necessarily STEM because they do not meet the definition of STEM education [33].

Latin America has not experienced the STEM boom, so it is not common to find elementary, secondary, and middle school institutions with the four disciplines separately or integrated, but it is common to see institutions with a focus on separate learning experiences in science or mathematics. On the other hand, technology is sometimes confused with computer science or robotics, while engineering is not even part of the basic, secondary, and middle school curricula, since it is conceived as exclusive to higher education [28].

Additionally, Morrison (2006) raises more bad practices and misconceptions about STEM education, such as i) that technology and engineering are not separate and isolated subjects within the STEM curriculum, ii) confusing technology with programming and office automation, iii) applying STEM without using the scientific method and experimentation in laboratories, iv) separating mathematics from science, and v) specializing teachers in their disciplines without promoting multidisciplinary teamwork.

The holistic approach of the four STEM disciplines seeks to remove barriers between these disciplines. STEM education seeks to promote educational transformations in teaching to achieve digital literacy, in educational objectives to develop new skills and knowledge, in educational institutions to improve infrastructure and management, in the role of the teacher to become a facilitator, in students to learn, in educational resources to adapt them to greater interaction and access to more information [35].

From the above definitions, it is necessary to recognize the benefits of STEM education, which is the focus of the following section.

Benefits of the STEM education

First, STEM education enables the development of skills for economic and social benefits [9]. In this regard, the U.S. National Academy of Sciences defined the set of skills required for an eminently technological workforce as 21st Century Skills. These skills of the 21st century are i) adaptability, understood as the ability to cope with changing working conditions [36]; ii) complex communications and social skills, enabling the processing and interpretation of verbal and nonverbal information to share ideas and concepts [37]; iii) non-routine problem solving, i.e. the ability to diagnose a problem and to be creative in coming up with new and innovative solutions [37]; iv) self-management and self-development, understood as the capacity to work autonomously in a self-motivated and self-controlled manner [36]; and v) systemic thinking, i.e. the ability to recognize how a system functions [36] to make decisions about their elements and interactions [38].

However, is possible to synthesize 21st century skills and positive attitudes toward STEM as engagement, interest, and self-efficacy [39], into STEM skills such as i) critical thinking, ii) problem-solving, iii) research, iv) creativity, v) communication, and vi) collaboration [28]. These STEM skills can be complemented by the competency of computational thinking, which is very important for STEM learning [40] and involves some 21st century skills and STEM skills, such as problem-solving, and systemic design although the theories of computer science [40]. However, the low rate of women in computer science and the low levels of computer science in more than two-thirds of U.S. high schools were numbers presented in 2010 by the report "Running on Empty: The Failure to Teach K-12 Computer Science in the Digital Age” [41]. These troubling numbers link computer science education to American science policy focused on STEM learning, given that computational thinking is considered the core of all STEM disciplines [42].

These STEM skills offer benefits to the inclusive learning spaces such as i) favoring real-time feedback, ii) promoting interest in science, iii) favoring synchronous and asynchronous communication, iv) avoiding marginalization and facilitating social and labor insertion, and v) saving time for the development of skills [43]. However, in the case of migrant and refugee children, STEM learning requires guaranteeing their access to Information and Communication Technologies (ICT), as well as teacher training and articulation with families for the use of ICT [44].

STEM learning for migrant and refugee children

The migrant and refugee populations should not be chosen as the target population because they are part of a vulnerable minority, but because of the previous social and cultural capital, they bring from their countries of origin. In this sense, it is key to understand that STEM education, although it is for all [28], therefore, educational interventions should be made at an early age, given that at this age they are developing a certain attitude towards STEM disciplines [8].

In addition, the literature on transnational education has studied the implications of migration on children's well-being, especially on their identity [45], academic aspirations, and success in school [46]. Despite these studies, educational policymakers continue to prioritize educational programs for adults, turning children into secondary actors, represented as the baggage of the parent who needs to study [47].

Therefore, according to Pain (2004), migrant and refugee children end up being invisible, losing their voice and perspective on migration [49], and missing opportunities to design transnational and on-the-move education programs focused on migrant and refugee children. These transnational educational programs for migrant and refugee children could include computational thinking for K12 through a STEM approach.

Computational Thinking at K-12 STEM Education

Computational thinking is defined as a process that involves the formulation of problems [50] and the representation of their solutions as algorithms [51] and applies computational techniques to understand natural and artificial systems [52]. These theorist definitions require the operational definition of computational thinking for K-12 proposed by Valerie Barr and Chris Stephenson [53], which allows articulation of concepts and capabilities with the educational resources for K-12 teachers that can be applied across STEM disciplines.

The integration of computational thinking concepts and capabilities into multi-disciplinary activities proposed by Barr and Stephenson was delineated for STEM disciplines and can be seen in Table 5. These concepts and capabilities are related to basic elements of the CT curricula that promote their learning and evaluate their development: i) abstraction, ii) systematic processing of information, iii) symbol systems, iv) algorithmic, v) problem decomposition, vi) Iterative and recursive thinking, vii) conditional logic, viii) performance constraints and ix) systematic error detection [54].

CT concept and capability	Computer science	Math	Science
Data collection	Identify a data source for a problem defined.	Identify a data source for a math problem.	Collect data from a scientific experiment.

Data analysis	Develop a program that calculates statistics on a set of data.	Count occurrences of flips and dice throw.	Analyze data from a scientific experiment.
Data representation	Apply data structures.	Apply graphs to represent data (histogram, pie, and bar chart).	Summarize data from a scientific experiment
Problem decomposition	Define functions, objects, and methods.	Apply order of operations in an expression.	Classification of biological species.
Abstraction	Use conditionals, loops, and procedures.	Use functions and variables in algebra to apply in programming.	Develop a model of a physical entity.
Algorithms and procedures	Implement algorithm for problem-solving.	Do factoring, division, addition, and subtraction.	Do a procedure of a scientific experiment.
Automation		Use computational tools (Star logo, Python code, …).	Use computational tools (Probeware).
Parallelization	Dividing up data to be processed in parallel.	Solve linear and matrixial systems.	Parallel run different experiments.
Simulation	Algorithm animation.	Graph variables and functions in different planes.	Simulate the movement of the solar system.

Table 5. Capabilities of computational thinking in STEM disciplines. Adapted by [53].

Having understood the STEM disciplines, their definition, and scope, as well as their benefits for learning in children through the use of computational thinking for K12 with a STEM approach, it is important to mention the advantages of STEM education for innovation and the success stories in which they are integrated.

STEM education for innovation

Based on the above conceptual framework, it is possible to mention the advantages of STEM education for migrant and refugee children in destination countries. In this regard, it is important to begin by differentiating between migrants and refugees. A migrant is someone who moves across a border, either within a country or across an international border, regardless of whether the such movement is voluntary or involuntary, regardless of their legal status (irregular or irregular migrant), and regardless of the length of their stay [55]. While refugee status is a legal category granted to any person in need of protection by the United Nations through the High Commissioner for Refugees, regardless of the recognition or membership of the country of destination in international treaties such as the 1951 Convention or the 1967 Protocol [56]. Understanding that within the migrant and refugee population, children are the most vulnerable, for which reason the Inter-American Court of Human Rights has reiterated the application of the principle of the best interest of the child and the non-separation of children from their families [57].

In this context, STEM Education is proposed as a holistic solution that contributes to the workforce of the four STEM disciplines [33]. Therefore, it should be assumed that STEM education is for everyone and is not exclusive to those students with STEM skills or with differentiated skills in one or more of the STEM disciplines. For this, all people must be included, especially minorities, in this case, migrants and refugees, who in the case of Latin America need to be included in the education system to transform these societies towards innovation [28]. Innovation is a purpose of

STEM Education for destination countries since learning in these STEM disciplines allows for developing solutions to real problems in each country [28], as shown below with STEM integration cases at different educational levels.

STEM integration cases

Among the success stories of integrating STEM Education into educational programs for children, the following four cases stand out: CSTEM Challenge, Build IT, TechBridge, and Engineering is Elementary.

The first case is the CSTEM Challenge, an annual competition for groups of elementary, high school, and middle school students to develop 21st century skills through the design of technological solutions for the business sector [58].

The second case is Build IT, with girls building information technology fluency through design, a 10-week, two-year, after-school summer program for high school girls that seeks to foster students' interest in algebra, geometry, and computer science in preparation for STEM disciplines in higher education [59].

The third case is TechBridge, a year-long after-school program for girls in grades 5-12, which promotes interest and develops skills in science, technology, and engineering to recognize the importance of racial diversity in fostering student engagement [60], as well as to enhance students' interest in STEM disciplines [61].

The fourth case is Engineering is Elementary, a program of the Museum of Science in Boston, which promotes the use of scientific theories following the engineering design process, as well as the understanding of these concepts for the solution of everyday problems [62].

Conclusion: STEM in the Inclusive learning spaces

In conclusion, STEM education to achieve inclusive education for migrant children is evident. Inclusive education should be understood as the educational process with the necessary services for all students to participate on equal terms in a regular classroom [63], in which diversity is valued and quality education for all is guaranteed [64].

Inclusive education has several challenges, which can be addressed with ICTs to ensure access to quality education for all, understanding that ICTs serve as prostheses to overcome social, economic, and cultural barriers presented by migrant children [65]. ICT in inclusive learning spaces i) eliminates barriers between teacher and student, ii) expands educational offerings, iii) makes teaching more flexible, and iv) facilitates interaction with the environment for students with special educational needs [66].

STEM education in the inclusive learning spaces requires: i) the adaptation of curricula to the educational needs of migrant children, ii) their full access to the learning environment, i.e., to an electronic device (cell phone, tablet, or computer) and to the resources offered by the Internet to access information and communication through networks, and iii) teacher training for the selection of the most appropriate technology to meet the needs of migrant children [65].

Finally, this literature review evidences that STEM education with ICT for migrant and refugee children has not been studied and requires further research. However, the 8 themes obtained seek to close this gap in the literature by recognizing that STEM education not only facilitates inclusive learning spaces but also allows for the elimination of asymmetries in knowledge and understanding of technology between teachers as experts and students as non-experts, ensuring that teachers in addition to being technical in their disciplines recognize the social practices of migrant children. STEM education seeks to present to migrants as end users, not only their benefits but also the risks of their technologies, to obtain the consented and informed use of the participating students.

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