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Science, Technology, Engineering and Mathematics "STEM" as a Teaching Method in Engineering

Ciencia, Tecnología, Ingeniería y Matemática "STEM" como Método de Enseñanza en Ingeniería

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ABSTRACT

Science, technology, engineering and mathematics describe the study of four of the great areas of scientific knowledge; and they are an initiative created by the United States government agency known as the National Science Foundation, which is dedicated to advances in research and education in all fields, not dedicated to medicine, related to science and engineering. The objective of this article is to use project-based science, technology, engineering and mathematics as a teaching method to stimulate the development of soft skills and the study of science and engineering, in undergraduate and graduate training. The research confronts theories and methodologies regarding the themes of advances and applications of engineering education through the study technique of science, technology, engineering and mathematics. As a result, science, technology, engineering and mathematics, contribute as a teaching method, providing aid in the achievement of specific timely and necessary achievements for industry and development through the transfer of knowledge, demonstrating that through these reduces student failure in studying science. It is concluded that extracurricular activities related to the prototyping and application of knowledge, strengthen the appropriation of science, technology, engineering and mathematics and help the student to break their paradigms.

Keywords:

Competencies, Education, Teaching, Engineering, Skills, Methods.

RESUMEN

La ciencia, tecnología, ingeniería y matemáticas describen el estudio de cuatro de las grandes áreas del conocimiento científico; y son una iniciativa creada por la agencia gubernamental de los Estados Unidos conocida como National Science Foundation, la cual se dedica a los avances en investigación y educación en todos los campos, no dedicados a la medicina, relacionados con la ciencia e ingeniería. El objetivo de este artículo es utilizar como método de enseñanza la ciencia, tecnología, ingeniería y matemáticas, basado en proyectos, para avivar el desarrollo de habilidades blandas y el estudio de las ciencias e ingeniería, en la formación de pregrado y posgrado. La investigación confronta teorías y metodologías referentes a las temáticas de avances y aplicaciones de la educación en ingeniería mediante la técnica de estudio de las ciencias, tecnología, ingeniería y matemática. Como resultado, la ciencia, tecnología, ingeniería y matemáticas, aportan como método de enseñanza, brindando ayudas en la consecución de logros específicos oportunos y necesarios para la industria y el desarrollo a través de la transferencia de conocimiento, demostrando que a través de éstas se reduce el fracaso del estudiante en el estudio de las ciencias. Se concluye que las actividades extracurriculares relacionadas con el prototipado y la aplicación del conocimiento, fortalecen la apropiación de las ciencias, tecnología, ingeniería y matemáticas y, ayudan al estudiante a romper sus paradigmas.

Palabras clave:

Competencias, Educación, Enseñanza, Ingeniería, Habilidades, Métodos.

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Introduction

Education is one of the fundamental pillars on which the different nations have focused to generate their development, that is why it is shown as the differential factor in each of the societies at local, national and global levels, so the constant advances in methodologies focused on teaching are present very often, but have wondered how engineering education has evolved and what role is occupying today.

Natural Sciences, Engineering and Technology are two of the great areas of knowledge declared by the Organization for Economic Cooperation and Development OECD whose mission is to design better policies for a better life, these great areas are also part of the daily growth of society due to its great advances over time in science, technology and innovation and the promise of better future developments, so the study and transfer of knowledge in these areas is positioned as a challenge to achieve constant scientific advances.

The methodology of education based on Science, Technology, Engineering and Mathematics (STEM) has taken an interesting role in the classroom to promote project-based learning, case studies, etc., also encouraging the development of soft skills in primary and secondary education by encouraging the study of science and engineering in undergraduate and graduate education. Therefore, this document will address issues such as STEM applications in the areas of knowledge mentioned, and how these have generated impact in different regions both nationally and internationally applications that have emerged through remote laboratories studied by the authors M.I. Alberto Pedro Lorandi Medina, M.I. Guillermo Herminda saba, M.S.I. José Hernández Silva and M. C Enrique Ladrón de Guevara Duran, educational kits and tools for electronics, robotics, natural sciences and even aerospace engineering as mentioned by authors D. López - Fernández, P. Salgado - Sánchez , I.Tinao and V.Lapuerta in the article named Challenge-Based Learning in Aerospace Engineering Education: The ESA Concurrent Engineering Challenge at the Technical University of Madrid etc, focusing that STEM education is the force to promote the acquisition of knowledge for the future workforce.

Materials and methods

This study deepens and emphasizes the search and confrontation of theories and/or methodologies concerning the subject of advances and applications of engineering education through the technique of study of Science, Technology, Engineering and Mathematics STEM and subsequent documentary exploration, which will be implemented for the study and comparison of theories, activities etc. Applied in the STEM field.

The execution of the research was developed in the exploratory scope, examining the field of engineering education applying the STEM methodology following as a pattern the sequence of development described in Figure 1.

Figure 1. Sequential diagram
Source: Author

The study of each of the advances and/or applications is carried out by means of a characterization of the information, referring to the topic of the objectives, methods, results and conclusions with the purpose of clarifying the panorama of the research carried out in order to guide the development of this work in a clear and coherent manner.

Therefore, by means of the sequence described in figure 1, the topics will be approached as shown in figure 2.

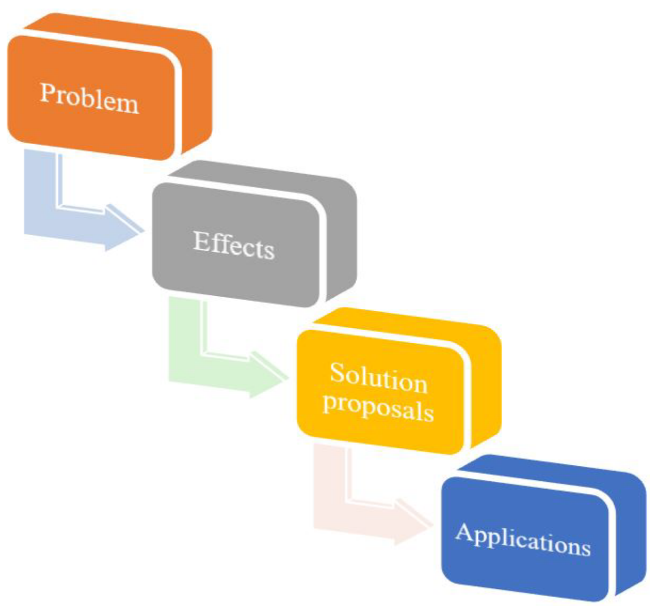

Figure 2. Thematic sequence of interest
Source: Author

Theoretical Frame

Apropos R N Irfiandaru, Abdurrahman and N Nurulsari in 2020, the learning process should be integrated with the scientific approach. In learning, the scientific approach is a feature and becomes a strength, and there needs to be the development of STEM-based teaching materials to support learning. STEM is an effective approach because it combines four disciplines, including science, technology, engineering and mathematics. Improving students' understanding of STEM is the key to success in raising student achievement in California. The use of STEM integration is proven to increase students' interest in learning in school, however the challenges in STEM education are not just technology, but teachers must be prepared to use the STEM approach. [1]

On the other hand, Kustina, Suratno and D Wahyuni in 2020 mention that biotechnology is a field of science that develops from a scientific interest, being very important to be understood by students because of its impact and potential on them and others. In honing students' skills in biology, especially biotechnology materials require learning that can help students improve their integrated knowledge with technology. Now, STEM education has been developed to be improving students' skills and it is very suitable if it is collaborated with biotechnology materials. STEM is an education that started to be seen by the government and educators in preparing the students needed in the future. [2] STEM education has been developed to improve students' skills and it is very suitable if collaborated with biotechnology materials.

The following researchers such as Elli J. Theobalda, Mariah J. Hilla, Elisa Trana, Sweta Agrawalb, E. Nicole Arroyoc, Shawn Behlingd, Nyasha Chambwee, Dianne Laboy Cintróna, Jacob D. Coopera, Gideon Dunstera, Jared A. Grummera, Kelly Hennesseya, Jennifer Hsiaoa, Nicole Iranonf, Leonard Jones, Hannah Jordta, Marlowe Kellera, Melissa E. Laceya, Caitlin E. Littlefieldd, Alexander Lowea, Shannon Newmang,h, Vera Okoloa, Savannah Olroyda, Brandon R. Peecooka, Sarah B. Picketti, David L. Slagera, Itzue W. Caviedes-Solisa, Kathryn E. Stanchaka, Vasudha Sundaravardanj, Camila Valdebenitoa, Claire R. Williamsk, Kaitlin Zinslia, and Scott Freemana mention that in 2019, a recent meta-analysis concluded that, on average, active learning in STEM leads to higher test scores and lower failure rates for all students

compared to all students in the same courses delivered through traditional lectures. However, several reports from biology, undergraduate courses also suggest that innovative course designs with active learning can reduce or even eliminate achievement gaps for MGS. [3]

However, Garousi Vahid, Giray Görkem, Tüzün Eray, Catal Cagatay, and Michael Felderer mention that in 2019 many software engineering graduates often face difficulties when starting their careers, which is mainly due to the mismatch of skills learned at university with what is needed in the software industry. The main objective is to perform a meta-analysis to aggregate the results of published studies in this area to provide a consolidated view on how to align software engineering education with industry needs, to identify the most important skills and also the existing knowledge gaps. [4]

From another circumstance the National University of Malaysia in 2019 unveils in its science, technology, engineering and mathematics (STEM) outreach report led by Sabirin Abdullah, Gan Kok Beng, Mardina Abdullah, Lilia Halim, Roslinda Rosli, Nurul Hajijah Hair, Muhamad Roszaini Roslan, Noridawaty Mat Daud, Mohd Azlan Shah Jaafar and Norisza Dalila Ismail where Selangor school students learned how to use an Arduino coding program to control mini helicopters. The students were instructed on how to assemble a simple circuit for the control system and how the circuit was connected to a microcontroller, which communicate with the computer. This equipped the students with basic knowledge to make the right program to move the helicopter. All learning activities were greatly facilitated by the undergraduate students through a teaching module. In addition, the program was conducted in the form of competition and this helped to bring out the competitiveness within the students. As a result, students were able to gain new knowledge within a short period of time. [5]

Continuing with robotics Habib Ahmed and Hung Manh La in 2019 indicate that the integration between robotics and education is essential to promote education and knowledge acquisition, which will lead to the training and development of the workforce of the future, thus exposing in their paper the exploration of the primary aspects related to education and robotics; one that seeks to utilize robotics education, primarily for science, technology, engineering and mathematics (STEM) related courses and another that discusses the use of different robots in the broader context for the purpose of facilitating education and learning for students of all ages. The proposal has implications at the national level, policy development in relation to STEM education, skills development at the professional level, as well as robotics education at the institutional level. [6]

In addition, Rodrigo Canek, Yeisson Chicas and Oscar Rodas in 2019 state that in the United States and Guatemala there is a shortage of engineers to be hired. Universities are not preparing enough students who choose scientific, technological, engineering or mathematical (STEM) areas as their career path. Our proposed outreach program has shown that participation in international and national robotics student competitions can ensure up to 75% of those students decide for a professional occupation in a STEM career path. [7]

On the other hand, Veronica Farr and Gerri Ligth in 2019 mentions that drone industries present a rich ecosystem for STEM careers; thus STEM development integrated the Drone Innovators Program, designed to immerse middle and high school students in STEM careers through drone education. The course design utilizes modeling research-based instruction to capture a wide range of student interests, skills, and abilities.[8]

Eric Nersesian, Adam Spryszynski, and Micahel J. Lee in 2019 comment on educational technologies (ET), monitoring bases (MB), and virtual reality (VR), applications that show promise for improving education. In their study they compared MB and VR technologies as alternatives for supplemental classroom learning through lectures, textbooks, and physics labs.

Ultimately, this research project serves as a basis to determine whether TEs have the potential to engage students.[9] In turn Tiago Lobato de Souza and Larissa Sato Elisiario in 2019 focused on the possibility of exploring the experience in educational robotics classes with Arduino and 3D printing for children and adolescents aged 10 to 17, they emphasize these two tools that can be very useful together to teach basic science, technology, engineering and mathematics (STEM) concepts. [10]

Dwight Bues in 2019 indicates that engineers often need to present a design and implementation proposals, speaking in front of a group. STEM students may be reluctant to publicly discuss their ideas and could use good role models, as this will definitely improve their performance in college and the business world. To a large extent, engineers have the math and science background to be subject matter experts, useful to be able to advise students within the particular STEM pursuit, this with the goal of helping engineers to "come out of their shells" by giving pointers on the methods and pitfalls of various types of instruction. [11]

Bryan Choate, Mia Dubosarsky, and Katherine Chen propose in 2018 innovative professional development (PD) for teaching robotics to educators with little or no robotics experience. Despite rapidly growing opportunities for K-12 students to participate in robotics, challenges, and competitions, too few robotics professionals have development opportunities, leaving educators unprepared to guide and coach their students. To address the need, the STEM Education Center at Worcester Polytechnic Institute (WPI) developed the Robotics for Educators program, a 5-day robotics program experience for K-12 educators in formal and informal settings. In the program's unique format, students and teachers learn together, participate in the same challenges, and assist each other in designing and programming robots. [12]

Likewise, Chanjin Chung and Elmer Santos in 2018 came up with a robot festival called Robofest being an informal learning program with multiple challenge learning interactives where students are challenged to complete robotics tasks. One approach that highlights this robotics carnival is that instead of professional technicians, the parents of the participants were trained for their children's collaboration in the event, which increased the knowledge of the students subject to STEM education; on the other hand it also increased the STEM confidence level of the parents who were trained by helping the carnival's learning stations. [13].

A holistic approach to integrating physical activities and programming into the classroom to encourage physical activity is the goal of CS+PA2, an effective learning model for teaching computer science, coding, and STEM concepts. As an example of CS+PA2 we taught an experiment, the "MathDance" program for seventh grade students using Tacha programming. The evaluation results (one evaluation taken before the activities, one after) show that the MathDance program improved students' math and computer literacy significantly. It also increased students' confidence in STEM classes and interest in STEM careers. Students who repeated MathDance moves did better, though not statistically significantly better, on a math and computer science test than students who did not, so ChanJin Chung and Mark Kocherovsky exposed in 2018. [14]

In view of currently suffering from abrupt weather changes and as an innovative idea Aamir Fidai, Mary M. Capraro and Robert M. Capraro in 2018 in a joint research work practicing the role of PBL (Project Based Learning) STEM activities, designing and building an electric bicycle. Traditional methods of engaging students in science, engineering, and math activities have proven insufficient to foster equitable engagement among students in underrepresented countries. Therefore, there is a critical need for approaches that foster equity, diversity, and inclusion in engineering fields that can increase the number of students from underrepresented populations in engineering. [15]

On the other hand, Clark M. Quintana in 2018 lays out a development of e-learning tool that facilitates the integration of science, technology, engineering, and mathematics (STEM) into plans for non-STEM selections. The e-learning tool is being designed to be widely accessible online and easily integrated with most K-12 curricula. The tool focuses on enabling students to actively explore STEM-related model dependencies without needing to understand the underlying math and science, which is the usual barrier. Users can explore various outcomes by checking various input values. This effort advances previous work by integrating features that are likely to increase attraction to STEM. [16]

From another point of view Deborah Hecht, Jennie Chiu, Ishwar Brigelal, and David Burghardt in 2018 state that research shows that STEM experiences in schools can influence career development. However, it helps students engage with science, technology, and mathematics practical concepts in out-of-school settings, although they can be particularly challenging as young people are often able between dropping out or leaving. Exploring how tablet-based technologies that support knowledge integration and informed design can support STEM learning outside of school. [17]

Garibay M. T, Gomez J. C, Terissi L, Soria L, Marcuzzi R, Moya M, Bertinat L, Massetti A, Neumann L and Chavarini A in 2018 took the initiative to implement a place where creativity, innovation and hands-on learning come together to improve engineering education. With these goals Space Maker was created; it is a facility where students can develop their own projects or projects proposed by faculty members such as in the areas of robotics, mobile networks and signal processing as part of the courses, allowing them to teach STEM as well as the skills for teamwork and to communicate ideas. [18]

However, Arturo Melo, Carolyn L. Beck, Jose Ismael Peña and Philip E. Para in 2018 mention that in developed countries it is necessary to understand how knowledge transfer (KT) occurs through human capital from universities to regions. Now, a KT model of human capital from university nodes to productive nodes is presented for seven

Colombian regions and examines how the proportion of graduates absorbed by each region generates new knowledge products, on the other hand the model tries to explain the dependence of knowledge products with science, technology, engineering and mathematics (STEM). [19] The model is based on a model of the KT of human capital from universities to productive nodes for seven Colombian regions and examines how the proportion of graduates absorbed by each region generates new knowledge products.

Seema Rivera, Mahesh K. Banavar, and Dana Barry in 2018 state that the use of mobile apps has been successful in the field of STEM education to college students. This method introduces science and engineering practices included in the Next Generation Science Standards (NGSS). The mobile app provides creative learning experiences for science and other STEM students. [20]

From a different criterion Michael S. Rugh, Julia E. Calabrese, Robert M. Capraro, Ali Bicer, Mary M. Capraro, and Luciana R. Barroso in 2018 state that STEM language may be the origin of the problem when communicating, furthermore linguistic research has shown that confusion about specific words may be due to many causes such as alternative meanings or senses associated with that word. The study identified and categorized patterns of words and phrases that caused confusion during an engineering assignment at a STEM camp. The results showed that confusion about the meaning of words inhibited participants from progressing towards task completion. [21]

In contrast, Katherine N. Vela, Ali Bicer, Cassidy Caldwell, Robert M. Capraro, and Luciana R. Barroso in 2018 conduct research on the effect science and technology, engineering, and mathematics (STEM) problem-based learning (PBL) activities have on single-sex classrooms and how these experiences affect students' attitudes toward STEM careers. To close the gap of women's underrepresentation in STEM, research suggests that single-gender classes should be implemented. [22]

Similarly, Amy Eguchi and Lisbeth Uribe in 2017 state that in educational robotics or robotics in education is the term widely used to describe the use of robotics as a learning tool. Educational robotics is an effective learning tool to promote and encourage students' STEM learning being a learning tool that enhances students' learning experiences through hands-on learning of the mind. [23]

In Australia in 2017 Robert Ross, James Whittington and Phat Huynh mention that it has been recognized for decades that there is a worldwide trend of a shortage of students graduating in Science, Technology, Engineering and Mathematics (STEM) disciplines. Despite the recognized need to boost productivity through research and development, the numbers of graduates from engineering disciplines have seen little growth over the past decade. Education providers at all levels recognized this downward trend and have created a vast array of different student engagement programs to both attract and retain students in the STEM disciplines at both the secondary and tertiary levels. [24]

According to Stehanie Purington, Alicia Gonzales, and Elizabeth McEneany in 2017, in most classrooms it is observed that "homework," teachers simply gave the instructions and let students get started. We would encourage a different path for future iterations. To start a conversation about the math needed to complete the project, we would first have students read the instructions, and then we would point to the question of where they are asked to brainstorm ideas for for mass production. We would ask if the students know what mass production entails and think that the discussion would begin by explaining and defining these concepts. [25] We would then ask them to brainstorm ideas for mass production.

On the brainwave side, Yu-Cheng Chien, Chia-Hung Lai and Yueh-Min Huang in 2017 did a study based on brainwave and sensor imagery to construct an attention recognition mechanism and apply it to develop a real-time neuro-feedback system that can maintain an effective learning state. Through the employment of attention recognition mechanism, this system can trigger a feedback to improve their attention in real time when students' reading attention was detected too low. Therefore, they developed a real-time neurofeedback to improve the learner's attention in reading e-books. In this, the participants had asked to use NeuroSky to read e-books during the experimental progress. Brain wave functions are automatically activated to detect the learner's attention. [26]

Melvin Goodwin, Jacqueline Healy, Kristen Jacksa and James Whitehair in 2017 laid out strategies to address the main barriers to STEM-based education with these barriers being related to standardized testing and educator engagement. Giving results initially from students to STEM-focused and STEM-infused lessons are overwhelmingly positive and managers have noted much higher levels during classroom observations. [27]

In turn in 2017 Jhannes Krugel and Peter Hubwieser explain that the prior knowledge of college freshmen varies greatly in the programming branch, giving themselves the task of creating a massive open online course (MOOC) representing a solution. Therefore, they designed and developed a MOOC called LOOP (Learning Object-Oriented Programming) that provides a gentle introduction to computational thinking and object-oriented concepts before the programming part. [28]

Although Aini Aziziah Ramli and Nor Hasniza Ibrahim in 2017 state that STEM education is an interdisciplinary approach that aims to educate students in four specific disciplines rather than teaching the four disciplines as separate subjects; STEM education integrates cohesive learning based on real-world applications. [29]

With the aim of achieving satisfactory results in the teaching and implementation of semester courses in control engineering, in which the presence of students from different disciplines is more than notorious Antonio Flores Caballero, Dorin Sabin Copaci, Alvaro Villoslada Pecina, Dolores Blanco Rojas and Luis Moreno Lorente in 2016 propose to resort to high levels of abstraction in the programming of control systems. This high level of abstraction comes from the use of a rapid prototyping system for advanced control, which allows to resort to functionalities that had not been foreseen in any rapid prototyping environment. The advanced nature of the system provides solutions from the highest level of abstraction, so-called model-based design, for the intricate relationships needed between control engineering and real-time computing, allowing students to focus their efforts on control algorithm development, system identification, and physical plant modeling rather than worrying about the tedious low-level management and configuration tasks of the hardware architecture they are employing. [30]

From a different perspective Cooke Laquana in 2016 mentions generative STEM education in game design-based learning stating that STEM Education K-12 test scores have been steadily improving over the last decade in the United States, achievement gaps remain for minorities and women in STEM courses and careers. Game-based, learning methods are common models of science and technology education that provide young people with extrinsically motivating knowledge learning frameworks, however, research has shown that even these procedural spaces are often disconnected from the social and cultural realities of students. [31]

Similarly, Kanyawit Klinbumrung and Somsak Akatimagool in 2016 developed a STEM-based instructional tool for transmission in the line engineering course. The research tool consisted of an experimental set and GUI simulation program for impedance and standing wave measurement characterization. [32]

Now, Karl Perusich in 2016 mentions the creation of an electric go-kart camp that started in 2013 as a way to encourage students to choose STEM as a possible career. This camp is designed to give an overview of the physics, electrical and mechanical engineering, engineering associated with the design and operation of a battery-powered go-kart. [33]

Regarding Fred J. Figliano and Gina J. Mariano in 2015 conducted a qualitative study with the goal of fostering the transfer of science, technology, engineering, and mathematics while working on engineering design problems.

Teaching for transfer provides a vehicle to foster transfer of STEM content through abstraction of knowledge in each individual discipline. Many theoretical approaches to explaining knowledge transfer are rooted in the belief that knowledge becomes generalizable through its abstraction.[34] Theoretical approaches to explaining knowledge transfer are rooted in the belief that knowledge becomes generalizable through its abstraction. [34]

As for David R. Granchelli and Chiamaka Agbaasi-Porter in 2015 unveil a laboratory in which they develop STEM programs that merge traditional academic classroom lectures with hands-on and experimental activities, with students having the opportunity to build and test engineering components based on the theory being taught. The lab is divided into two settings, for high school students and for engineering students, both programs involve intensive classroom lectures and hands-on activities that require students to execute. [35]

Being environmentally friendly Alexander Proulx, Anthony D'Amico and Charles Thangaraj in 2015 designed and implemented a miniature horizontal wind turbine demonstration kit for K-12 STEM programs; in their paper they describe the design and prototyping implementation process.[36] In their paper they describe the design and implementation process of prototypes.[37] In addition to the above, they have also designed and implemented a demonstration kit for K-12 STEM programs.[38] In their paper they describe the design and prototyping process.
However, Ramakrishnan Sundaram in 2015 spearheads an outreach program called "STEM Time" for K-12 STEM teachers. Such a program denotes training in engineering skills and encompasses the engineering education program, pre-engineering curriculum and cyber instructional networks. Teachers will be better prepared to teach STEM concepts and will advance their careers in STEM and engineering technology. [37]

From another perspective Diego Bautista Diaz, Francisco Suarez Moreno and Jhonny Gomez Amaya in 2019 expose their experience carried out from the subject Technology and Computer Science, with a high school course, in the course of grade 9 to grade 10, in a public school in Bogota, Colombia. The main objective of this experience was the development and application of a curriculum plan based on the STEM (Science, technology, engineering and mathematics) approach in order to enhance some of their competencies (knowledge, skills and attitudes), as a contribution to the development of their skills and vocation for engineering careers. A quasi-experimental design was carried out with ninth grade students. The STEM approach, seeks to integrate the contents in a new disciplinary set, enhancing thinking processes (creative and critical) and problem solving. [38]

Now, researchers Pedro Bravo Mosquera, Nelson Cisneros Insuasti, Bryann Avendaño Uribe and Fabiola Mosquera Rivadeneira propose in 2019 a STEM learning based on aircraft design, with the aim of promoting the development of aeronautical science in Colombia. This teaching strategy was developed by specialized instructors from the Clubes de Ciencia Colombia program, seeking to stimulate in young Colombian students their passion for science, technology and innovation, and in the process create an international network of academic collaborators.[39]

However, Cristian Ferrada, Danilo Diaz Levicoy, Norma Salgado Orellana and Eduardo Puraivan in 2019 perform and describe the results of a bibliometric analysis of STEM scientific production in the SCOPUS database, between the years 2010 and 2018. The study consisted of analyzing a total of 65 documents published in that database, with the variables provided therein. The results show that STEM education is a proliferating topic, by identifying the relevant areas and key words on the subject, as well as the countries and media in which they are published.[40] The results show that STEM education is a topic in proliferation.

On the other hand, Gonzalo Bonilla Bravo, Jon Azcona Esteban, Luis Javier Ulloa Meneses and Willian Javier Ocampo Pazos in 2018 make known the importance of the practical component within a career such as engineering and present to the community an alternative that serves as part of a perfectly applicable educational environment. To this end, STEM (Science, Technology, Engineering and Mathematics) education is introduced, which is an emerging trend that seeks modular, adaptable and easy-to-use tools that help the student in the process of practical teaching. In this particular case, the Arduino platform has been chosen as an applicative, due to its large community and existing free hardware movement. [41] The STEM (Science, Technology, Engineering and Mathematics) program is a program that is based on the STEM (Science, Technology, Engineering and Mathematics) program.

The STEM (Science, Technology, Engineering and Mathematics) Robotics UNIMINUTO-iCargnegie program headed by Viviana Garzón Cardozo in 2016, develops competencies of high school students in STEM areas and enhances 21st century skills. This program exemplifies the pedagogical perspective of learning-by-doing, focused on the study and based on the formulation of projects, design and exploration of challenges and modeling of roles and responsibilities of engineers. The program develops these skills using the knowledge of professionals in different areas of engineering such as: programming, flowcharts, pseudocode, mechanical models, C programming language, sensing, mobile robotics, among others. [42] The program is designed to develop the skills of engineers in the 21st century.

Results and Discussion

Discussion Problem

Two of the major areas of knowledge that contribute the greatest amount of scientific and technological progress in humanity are the Natural Sciences and Engineering and Technology, from which there are a number of areas and disciplines of study that involve in most of their knowledge the natural sciences, engineering and technology.

In different parts of the world, the lack of interest of young people in studying the disciplines of these areas is evident [7] and [24], one of the possible causes of this problem would be reflected by the assignment of tasks without any instruction, where the student would have to face science problems without specific guidance from a tutor, according to study addressed by [25]. Another cause of young people's disinterest in the study of scientific careers is the lack of knowledge on the part of educators about the social and cultural realities of multi-gender students, as explained by [31], as well as the gender inequity in the choice of young people to pursue professional programs in science according to their biological sexuality and/or diversity, as indicated by [22] in his research. These contributions and research studies reveal three main factors that are presented as causes of the low demand of young people interested in pursuing careers in the areas of science, engineering and technology. These causes are described sequentially in Figure 3.

Figure 3. Causes of low demand for young people interested in science, engineering and technology

Source: Author

Effects Analysis

As mentioned by [7], the lack of engineers in countries such as the United States and Guatemala is evident in the industry of these countries, reducing the number of qualified personnel to occupy positions in which personnel must be trained in science and technology activities. The low demand causes the transfer of knowledge to companies and regions to be limited, as mentioned by [19]. Developed countries face this type of effects by motivating and devising different programs to maintain or transmit the interest to be educated in engineering and science careers. Colombia is one of the countries that, although in some of its regions it has improved, there is still a lack of motivation among young people to study careers related to engineering and technology, causing the effect described in Figure 4.

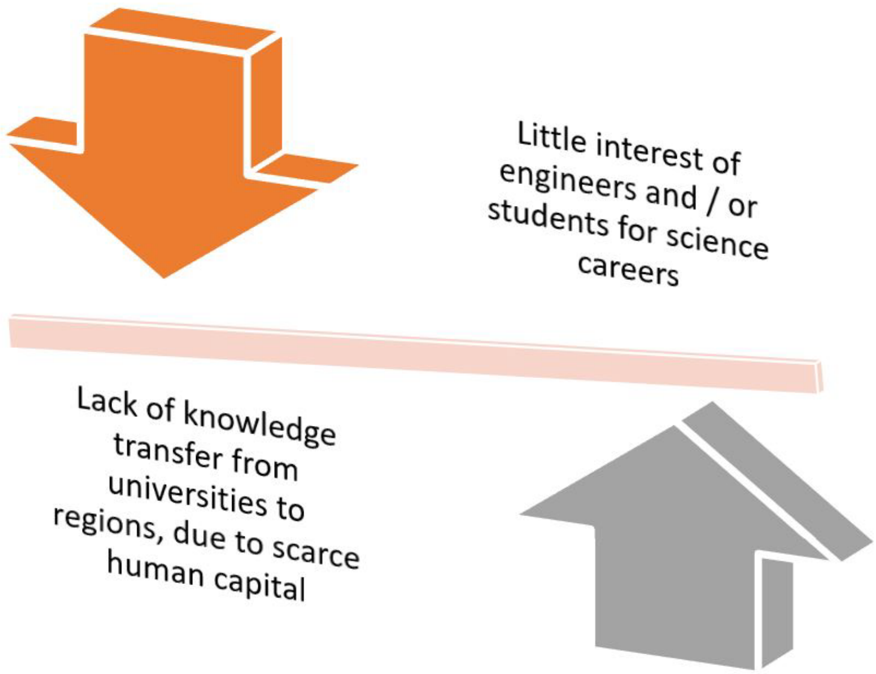

Figure 4. Cause effect diagram
Source: Author

Results for Solution Alternatives

Giving timely response to the need to encourage young people to choose to study careers related to science and engineering, led different researchers to join in the task of focusing efforts to devise strategies to solve the lack of scientists, which is why in the mid-90s and as a pioneer the National Science Foundation which is a government agency of the United States promoted the STEM initiative, which focused on the study of four of the major areas of knowledge in which its main actors are scientists and engineers.

The STEM has shown evidence that through this initiative, it is involved towards the acquisition of active learning, providing aids in achieving specific achievements quite timely and necessary for industry and development through the transfer of knowledge that is why [3] and [29] through their research show that through this it reduces student failure in the study of science. As learning models, PBL is linked which is the project-based learning methodology through instructions or research, because of this [8] and [9] based on this methodology PBL added to STEM show how students combine interests, skills and abilities in the acquisition of specific knowledge with projects such as building drones or learning through virtual reality, while [15] through the construction of an electric bicycle shows how trainees developed their skills and met the expected expectations.

Other teaching modalities linked to STEM are MOOCs for its acronym in English, which are focused as massive open online courses and LOOPs which are object-oriented programming apprenticeships [28] and [41] show how software engineering can be taught based on STEM through the methodologies mentioned above, contributing to knowledge transfer and industrial growth in the development of computer science and engineering and based on learning the skills needed for industry 4.0. Figure 5 shows a hierarchical order of how the methodologies used for STEM are used in some sectors.

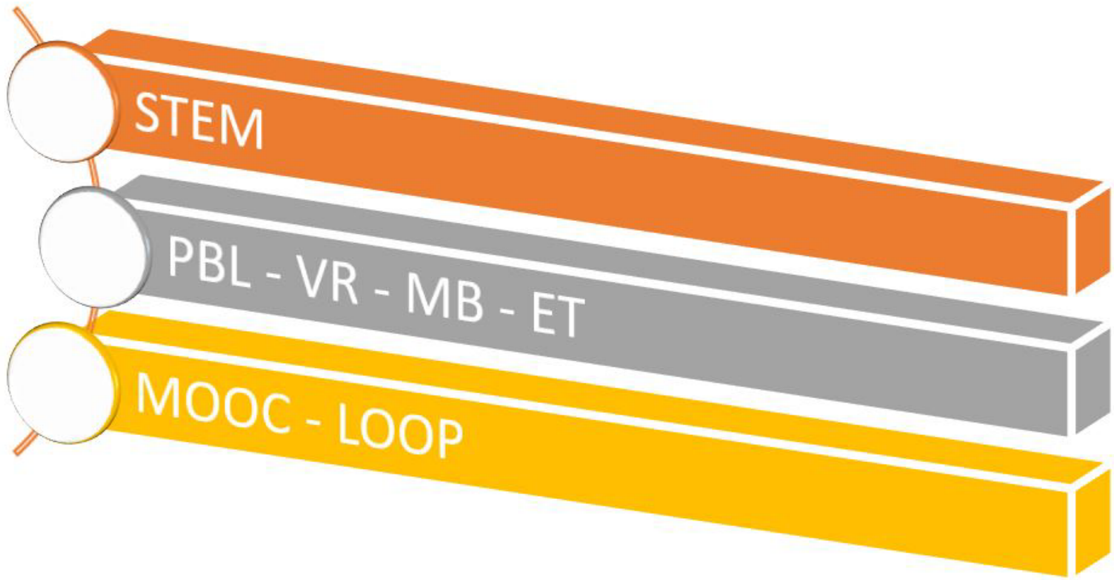

Figure 5. Hierarchy of use of STEM-based methodologies

Source: Author

Applications

The developments achieved in science, technology, engineering and mathematics as sub areas of specialized knowledge, motivate the actors interested in knowing first hand the progress generated, that is why the sample of how engineering education has evolved and what role it is currently occupying regarding issues such as the applications of STEM in the 4 specific areas of knowledge, and how these forge footprint in dissimilar national and international territories. Some of the areas of application for STEM are those mentioned in Figure 6. Research such as that of [17] shows that STEM experiences influence the development of careers where it is implemented, as well as [18] shows in his study that through the creation of a facility called Space Maker students learn skills in robotics, mobile networks and signal processing.

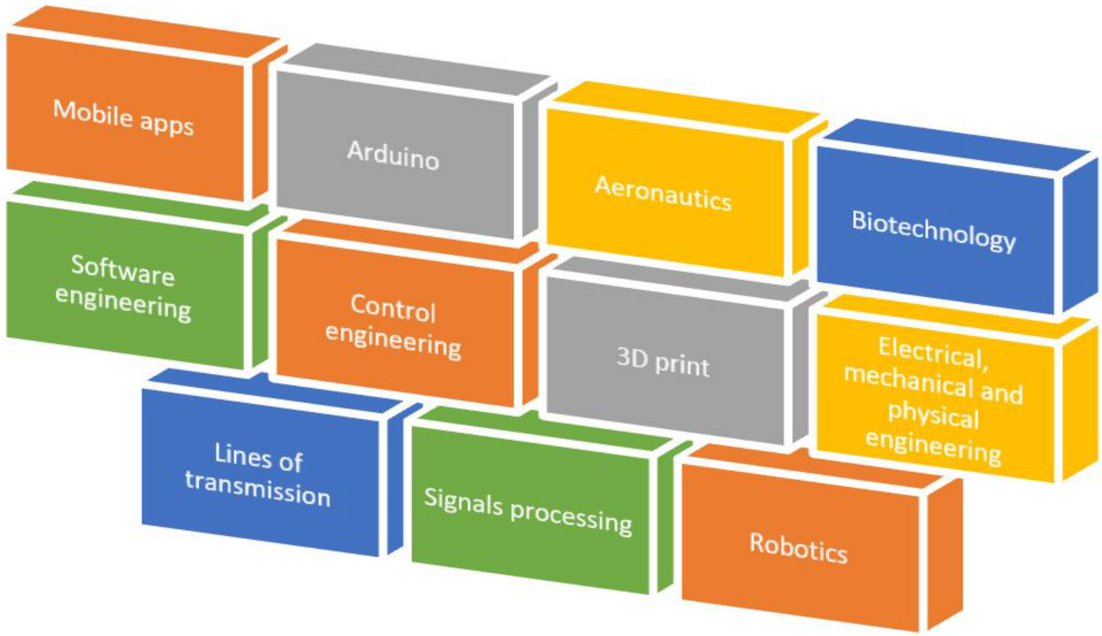

Figure 6. STEM application areas
Source: Author

Control prototyping is another field that can be studied using STEM, so [30] mentions the so-called model-based design, for the intricate relationships needed between control engineering and real-time computing, allowing students to focus on control algorithm development, and identify systems and physical plant modeling instead of worrying about management and configuration tasks. On the other hand [32] applies a transmission line-based instructional tool using GUI simulation software for impedance and standing wave measurement, facilitating student understanding, for [33] and [34] STEM can be approached through knowledge abstraction experiences, through activities where the student is invited to develop their capabilities in seeking and achieving goals for a specific purpose...., through the construction and testing of engineering components based on the theory that is taught, as mentioned by [35] the use of kits such as wind turbines which are used by [36] allow the student to study the design and prototyping to get into the specific operation of wind turbines, the design of aircraft is one of the bets of [39] to get into the teaching of prototyping and operation of aircraft and the study of free hardware based on the research of [41]. The ICARNAGE strategy of [42] shows the applications of one of the higher education institutions in Colombia to teach robotics through STEM with the methodology of learning by doing and involves the PBL methodology to achieve the proposed objectives, confident that the student can develop their skills and be prepared to meet the needs of the market. That is why STEM is positioned as one of the main source to prepare future scientists and engineers to face the transfer of knowledge on issues related to Industry 4.0 and the needs of the market, industry and education, etc.

Conclusions

Science, technology, engineering and mathematics are positioned as a strategy in the teaching-learning process, to achieve meaningful student learning.

The teaching-learning process, supported by science, technology, engineering and mathematics, leads the student to active learning, contributing to the development of personal capacities and abilities.

The experiences of science, technology, engineering and mathematics influence not only the abilities of the student, but also the development of careers with a scientific approach.

Extracurricular activities related to the prototyping and application of knowledge, strengthen the appropriation of science, technology, engineering and mathematics and help the student to break their paradigms.

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