El modelo de ciencia, tecnología, ingeniería, artes y matemáticas (STEAM): su pertinencia para la educación en línea

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RESUMEN

El presente artículo aborda un modelo educativo también conocido como educación en ciencia, tecnología, ingeniería, artes y matemáticas (STEAM). El objetivo fue realizar una revisión teórica sobre el modelo STEAM y su importancia en la educación en línea. Este sistema tiene como finalidad la formación de estudiantes y nuevos profesionales con competencias hábiles y prácticas, capaces de liderar procesos productivos y económicos para contribuir al desarrollo de sus entornos sociales. Los hallazgos muestran que aunque no ha sido una tarea fácil para los docentes la importancia de incorporar el modelo STEAM, como ha sido decisiva y vital, porque el ser humano necesita inspirarse y motivarse para realizar investigaciones que generen conocimientos basados en la ciencia. Se recalca la importancia que ha adquirido esta metodología educativa especialmente en la educación en línea, y los elementos para la creación de lecciones y aulas bajo este modelo. Además las competencias y retos que actualmente tiene, así como los beneficios y ventajas que pueden desarrollar los estudiantes que se forman con este sistema. Este modelo educativo ha cambiado la vida de profesores y alumnos, para fortalecer la enseñanza y el aprendizaje de la formación en línea.

Palabras clave: *aprendizaje en línea; aprendizaje activo; competencias del docente; modelos educativos; formación del estudiante*

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The Science, technology, engineering, arts and maths model (STEAM): its relevance to online education

ABSTRACT

This article addresses an educational model also known as science, technology, engineering, arts and mathematics (STEAM) education. The objective was to conduct a theoretical review of the STEAM model and its importance in online education. The purpose of this system is to train students and new professionals with skillful and practical competencies, capable of leading productive and economic processes to contribute to the development of their social environments. The findings show that although it has not been an easy task for teachers the importance of incorporating the STEAM model, as it has been decisive and vital, because the human being needs to be inspired and motivated to conduct research that generates knowledge based on science. The importance that this educational methodology has acquired, especially in online education, and the elements for the creation of lessons and classrooms under this model are emphasized. In addition, the competencies and challenges that it currently has, as well as the benefits and advantages that students who are trained with this system can develop. This educational model has changed the lives of teachers and students, to strengthen the teaching and learning of online training.

Keywords: *Online learning; active learning; teacher competencies; educational models; student education; student training.*

INTRODUCTION

As a result of the covid-19 pandemic, online education gained much strength, since it was the only way to reach so many students worldwide, but it required effective strategies that could channel the teaching and learning of the various subjects in a relatively short time, but that would serve to maintain the student's attention and understanding of this knowledge; One of which responds to the STEAM model, which emerged in the United States in the late 1990s with the National Science Foundation (NSF), the National Science Foundation of the United States, which used the acronym STEM in the scientific and technological field to group the fields of knowledge (science or technology or engineering or mathematics), but without any interdisciplinary connection.

In 2009, STEM emerged as a new concept in education, the acronym of four academic disciplines which are Science, Technology, Engineering and Mathematics, i.e. Science, Technology, Engineering and Mathematics, being in Spanish its acronym CTIM and in German MINT Mathematik, Informatik, Naturwissenschaft and Technik, where it is widely used (McComas and Burgin, 2020). In 2011, the US National Science Foundation (NSF) and the United States National Research Council (USNRC) identified these disciplines as fundamental to technologically advanced societies (Nawaz and Koç, 2020).

However, the structure of the STEAM approach began to develop just over a decade ago with the goal of achieving a holistic and integrative education, capable of adapting to the many disciplinary combinations that make up the different directions pursued by individuals in society (Aguilera and Ortiz, 2021). This broadening of the disciplinary range is seen as a significant advance over its predecessor, claiming that focusing on STEM without the "Arts" necessarily excludes important areas that inform and contextualize the science (Ortiz-Revilla *et al*., 2020).

Currently, in the United States there are 26 million jobs linked to STEAM areas, whose salaries are higher compared to other fields of knowledge; worldwide, statistics register a 20% of the labor need that requires STEAM areas and an increase is expected in the coming years; a 17% growth of this field in the United States, according to a report of the Department of Commerce of that country, which

reveals that this area is in constant development because graduates and new professionals are in high demand in a highly competitive and demanding labor market for creative talents based on knowledge (Allina, 2018). In this context, the objective of this research is to conduct a theorical analysis on the STEAM model and the importance of its application in online education.

LITERATURE REVIEW

The STEAM model or approach

STEAM learning is an educational model that pursues the integration and development of scientific-technical and artistic subjects in a single interdisciplinary framework (Montés *et al*., 2023). It is a new learning model based on teaching the four disciplines in an integrated manner instead of separate knowledge areas, with an interdisciplinary and applied approach (Basque Innovation Agency, 2017). It consists of an education based on an approach to learning that tries to eliminate the traditional barriers that separate the four disciplines by integrating them in a real world with rigor and that provides relevant learning experiences for students (García and García, 2020).

This educational model emerges as a proposal that aims to solve such problems, from an approach that privileges the teaching of integrated sciences with emphasis on their applications in the real world (García *et al*., 2017) and works as "a transforming element of education by promoting new roles among participants (teachers and students), diversification of scenarios and contexts, greater access to resources and the expansion of spaces for interaction and collaboration to build knowledge" (Santillán *et al*., 2020).

Thus, it can also be interpreted as an approach for the teaching of science, technology, engineering and arts in an interdisciplinary way (López *et al*., 2020); in order to make students literate and provide them with competencies, skills and abilities, so that they can contribute with solutions to social problems, through the application of didactics and its various elements that through mechanisms of simulation of needs can achieve the emulation of a reality (Zamorano *et al*., 2018).

It also constitutes one of the educational approaches that has taken greater relevance is STEAM which aims to establish connections between science, mathematics, technology, engineering and the arts to

solve problems in real environments in a creative and collaborative way (Wannapiroon and Pimdee, 2022); since it strives that the student questions, reflects, appropriates, transmits judgments and knowledge of the areas that are articulated in scenarios that stimulate cooperation, becoming agents of innovation, with competencies in research and provided with tools (Hafni *et al*., 2020), which serve them to face the new challenges of world globalization, being more than necessary, it is vital to apply it to train new students as problem solvers of various kinds, from minimal to high complexity (Simarro and Couso, 2018).

STEAM has acquired great applicability in the different areas of academic, scientific, and technological knowledge, as well as a very important pedagogical value for the development of digital competences and the learning of knowledge. Thus also, through humanistic (arts and design) and scientific (science, technology, engineering, and mathematics) interdisciplinarity, tinged by expressions and imagination, perceptions, creativity for the formulation of scientific and artistic projections overflow, which denote the effective pedagogical application of this educational model (Santillán *et al*., 2019).

Importance for online education

According to studies by the Institute for the future of education of the Tecnológico de Monterrey, it is very important to have a clear understanding of the significance of the areas that make up the STEAM model, thus, the "S" for science is a field that covers problems such as global warming, climate change or medicine. The "T" for technology ranges from computers to the digital age with Artificial Intelligence and programming. The "E" for engineering encompasses infrastructure, building design, cities, and bridges. Finally, the "M" for mathematics that can encompass fields ranging from economics, accounting, investments and taxes, analysts and even cryptographers (Rao, 2019).

Thus also, the importance of applying STEAM education to non-conventional online education, lies in the development of an interdisciplinary approach to the teaching-learning process, effectively combining the five areas of knowledge involved through their common elements that include

everyday situations that require practical solutions and the use of available technological tools; making its application yield "positive results, precisely because in one of its acronyms is art as a principle of it, on the other hand, a favorable result is obtained in the thinking of students"(Gil-Quintana *et al*., 2020), since thanks to the incorporation of the arts a much more meaningful, motivated, committed and relevant learning has been fostered in all STEAM areas (Oliveros, 2019); whose educational integrality has broken many educational barriers, it is promoting several perspectives that combine science, technology and art, making the approach to the teaching-learning process more practical, experiential and active (Belbase *et al*., 2022).

The practice of STEAM education contributes to the development of skills and prepares young people for the labor market, but demands knowledge with transcendence, with contextualized and creative meaning (García and García, 2020); which together with its practical response to labor needs, explains its positioning in education, quite apart from the fact that students have opted for online or traditional training, and that they may have certain limitations in these areas of study and show little interest in the STEAM professional profile; It is precisely their practice that is channeling them towards their practice, redundancy aside, and has led many countries to focus their attention on this education to achieve national production goals that contribute to strengthening their economies (Forero and Castro, 2022).

In the same context, all STEAM educational processes are aimed at the student learning to learn, discerning from among the large amount of information, that which is useful and can apply it also using the information and communication technologies (ICTs) widely used in online training, since he has developed the capacity for self-learning that will allow him to do so throughout his life (Monzón, 2019); since great changes have been generated in the pedagogical structure, thanks to the development of technological literacy and its use in the classroom through digital competencies; a new panorama that is responding to the demanding and changing market demand, since there is a trend of exponential growth in technology competencies in the long term (Adell *et al*., 2019).

Components and challenges of the STEAM model

The Horizon Report in 2017 - K12 edition establishes some fundamentals among which are short-term trends such as programming literacy and increased STEAM learning (Quigley *et al*., 2020), in addition to these, other authors converge on three components and three challenges that STEAM education aims to combat, as shown in Table 2.

Table 1 STEAM components and challenges

Components	Challenges
Contextualization of learning	Responding to economic challenges in many countries
Participation in authentic practices (inquiry and design)	Generate a skilled and competent workforce fit for the 21st century
Need to offer spaces for exchange and reflection to make thinking visible	To meet the growing demand for STEAM training in order to provide solutions to technological and environmental problems

Characteristics of STEAM students

According to several theorists, the differences between traditionally trained students and those trained with STEAM methodology are visible, whose characteristics include reflective risk-taking, persistence in problem solving, working through the application of creative processes, participation in experiential learning and the adoption of collaboration as a central element for obtaining practical results (Bequette and Bequette, 2012; Aguilera and Ortiz, 2021; Celis and González, 2021). These characteristics provide them with confluent qualities that give them a special character as the educators, leaders, and innovators of the 21st century that the business field demands so much to promote a sustained and sustainable socioeconomic development, in time and in the environmental setting (López *et al*., 2020).

In the field of education there is a latent need to energize education at all levels, and more so when it comes to online education, considering the fact that the student is organized in time and space to meet

their academic activities; in view of this, STEAM education is essential to be included in an integral way in classes, therefore, one of the ways to use it is the creation of lessons that include six fundamental elements, namely: teamwork, incorporating hands-on learning, making content relevant; turning mistakes into positive learning moments, being creative and taking advantage of the current tools at hand (Belbase *et al*., 2022).

METHODOLOGY

A systematic documentary review of the literature was carried out in accordance with the methods recommended in the PRISMA 2021 guidelines. The search was conducted through different academic platforms such as PubMed, Scopus, WoS, Science direct. The search strategy was to place keywords such as (STEAM model, online education, online learning, teacher competencies, educational models, student training) individually or combined. The literature search was limited to the most recent studies covering the period 2019 2022.

All eligible studies that met the following inclusion criteria were included: 1) studies in virtual modality, 2) containing the STEAM model in their title, 3) student-oriented, 4) teacher-oriented, 5) applied to the field of Education. Excluded were 1) studies that were reviews or editorials, 2) case reports, commentaries, opinions, or preclinical studies; 3) descriptive studies and 4) duplicate articles.

RESULTS AND DISCUSSION

Table 2 shows some elements and suggestions that teachers can use to develop lessons using STEAM methodology.

Table 2 *Creating lessons with STEAM*

Elements	Sugestions
Workteam	To encourage this, it is important to explain to students what the activity or project will be about, give clear instructions and time to plan. When grading assignments, consider how students use their skills to complete the assignment as a group rather than whether the assignment has been completed.
Incorporate hands-on learning	Lessons involving any of the STEAM areas should include research and exploration. The content should motivate the student to want to know more, to come to their own conclusions, and to design their own investigations to apply what they

	discovered, developing critical thinking by discarding information that does not support their analysis.
Make content relevant	The biggest advantage of STEAM education is that it involves issues that affect students in their day-to-day lives, so focusing the lesson on real-world facts and problems can captivate them. In addition, understanding the problem and learning the basic concepts can lead the learner to innovate, which is another powerful skill that employers are looking for.
Turning mistakes into positive learning moments	By discussing failure in lessons, teachers demonstrate that it is an essential part of learning. One of the advantages of STEAM fields is that they allow for trial and error, giving the opportunity to create and develop different solutions to problems.
Be creative	Employ arts and design tools and strategies in students, individually or in groups without fear, to achieve effective learning and understanding of knowledge.
Leveraging current tools that are at hand	There are several platforms to support online and conventional education, which contribute greatly to student training due to their practicality and ease of use.

Kartini and Widodo (2020) study established several benefits of STEAM education, including those described in Table 3.

Table 3 *Benefits and advantages*

Benefits	Advantages
Facilitates concept retention	Improve learning process through the exploration of concepts
Promotes proactive learning	Experiment with their own hands, they can see what the process is like, fail and build again.
Train problem-solving skills	It teaches how to solve problems using critical thinking skills
Trains logical mathematical thinking	Apply learned concepts to real-life practical cases.
Enhances communication skills	Foster the ability to transmit ideas and contributions to others.
Integrates ICT learning	Able to translate their creations using technological tools.
Improves creative capacity and imagination	Develop imagery harmonized with knowledge to contribute to their own and their peers' education.
Develops fine psychomotor skills	Acquire skills by using hands to create manual arts and crafts.
Develops emotional management	Promote positive thinking focused on contributing effective ideas.
Stimulates confidence and self-	Young people are introduced to future STEAM-related careers.

esteem	
Promotes teamwork	Learn to work as part of a team, because collaboration is an important component of this teaching.

Several theoretical foundations on STEAM methodology reveal the various conceptions that have been gaining ground and gaining strength in educational systems through classroom and non-classroom practice and discourse, and that conceive some competencies that can be achieved with this system. Table 4 shows the 16 dimensions and seven competencies that Sánchez (2019) refers to in his study.

Table 4 *Dimensions and competences*

Competences	Dimensions
Entrepreneurship and autonomy Undertake and carry out a project or purpose on one's own initiative.	Learning to learn Autonomy and personal development Entrepreneurship
Colaboration and comunication Achieving goals and objectives, solving situations, addressing group problems, and sharing knowledge.	Expresion and comunication Colaborative work
Knowledge and use of technology To be technologically literate. Understand and explain technological products and know how to use them, being aware of the precautions and consequences of their use.	Technological culture Use of technological products
Creativity and innovation Solve situations or problems in each context in an original and imaginative way.	Creativity and innovation
Product design and manufacture Design and construct simple objects and devices with a prior purpose, planning the construction and using appropriate materials, tools and components.	Design Manufacturing Planning and management
Critical thinking Interpret, analyze, and evaluate the veracity of statements and the consistency of reasoning.	Logical thinking Systemic thinking

Problem Solving	Obtaining and processing information.
Identify, analyze, understand, and solve problem situations where the solution strategy is not obvious.	Computational thinking. Problem-solving process.

There are experts who establish six steps to creating a STEAM-centered classroom, regardless of the subject area taught. In each step, the learner is working on both content and art standards to address a central problem or essential question (People's Bank, 2023), as can be seen in Table 5.

Table 5 *Creation of a STEAM classroom*

Steps	Contents
Clear approach	Students select a question or problem to answer or solve. Teachers must clearly establish this starting point, checking that it complies with comprehensive learning.
Correlated details	Students initiate their research and discover relationships between the different subjects of study, which allow them to identify why the problem exists and how to approach it from different perspectives.
Discovery	This is the active inquiry phase, where students look at solutions to the problem that are not working and propose their own solutions. Teachers help students here to overcome gaps or explicitly teach skills or processes that will help them in creating their solution.
Aplication	Students move on to practice, using knowledge and skills to create a practical solution to the initial problem posed, in a prototyping phase.
Presentation	It is an important phase to be able to share the results of their findings and the solution obtained with the rest of the class and thus receive feedback. Students learn to give and receive feedback.
Cycle closure	Students could revise their solution and incorporate the reflections of other students, and produce an even better solution, if necessary.

STEAM education has acquired substantial importance in the last decade of the 21st century, which is due to several reasons, from its emergence as STEM to its evolution as STEAM and the emergence of its i-STEAM, STR2EAM. The basis of this educational methodology is centered on the person as the entity that creates and recreates a system, a model, an innovative way of educating children,

adolescents, young people, and adults using a mechanism that works, and that has been demonstrated from the classroom to the business world, which is one of the direct beneficiaries of STEAM education.

The integration of STEAM education in the 21st century has been heralded to improve the quality of education, and its application has led to a focus on the factors that influence teachers' intentions to leave. Wijaya *et al*. (2022) argues that perceived usefulness had a positive impact and was related to teachers' attitudes toward STEAM education. Habituation had a positive impact on teachers' behavioral intentions and implementation. These results are recommended to address analytical problems and successfully enhance future learning through a didactic approach.

As Han *et al*. (2021) state, social, motivational, and educational factors influence students' STEM learning achievement and career paths. The results of this study revealed direct and indirect effects of teacher self-efficacy and outcome expectations on students' STEM knowledge attainment. Students' STEM attitudes (self-efficacy and perceived expected value), 21st century skills, and STEM career awareness also had significant direct or indirect influences on their STEM knowledge.

In a study of Lavi *et al*. (2021), general skills were rated higher than STEM-specific skills or soft (interpersonal) skills, while STEM-specific skills were rated higher than soft skills. Content analysis revealed nine teaching and learning methods used to develop the skills. Four active methods had a small effect on general competencies, while five passive methods had a moderate to large effect on these competencies. Active methods had a moderate effect on STEM-specific skills and interpersonal skills, while passive methods had no effect on either of these groups.

Guiding students to think critically and creatively is an important part of the educational process to equip them with the skills they need in the 21st century. Sumarni and Kadarwati (2020), Emphasizes that STEAM project-based learning can increase students' average critical and creative thinking skills in all indicators from low to medium categories. In conclusion, STEAM project-based learning has demonstrated a significant impact on improving students' critical and creative thinking skills.

The effectiveness of STEM implementation begins with students' higher order thinking skills,

continues with students' academic learning outcomes, and ends with motivation. In addition, STEAM implementation in Asia has adopted several variants, with a preference for STEAM integrated with project-based learning (Wahono *et al*., 2020). The recommendations of the authors include a combination of learning approach, learning orientation, and teaching duration, all of which contribute to the effectiveness of STEAM activities and maximize STEAM education outcomes. STEAM education is a universally important tool that effectively prepares students from diverse national and cultural backgrounds in Asia to achieve better learning outcomes.

CONCLUSIONS

It can be said that STEAM is a revolutionary education that has come to change the lives of teachers and students, managers and entrepreneurs, public and private officials, mothers and fathers, and the whole society; it has taken the classrooms by surprise to reactivate them, to shake them and make good things happen when students begin to awaken their abilities, to develop skills, to realize that they have skills and aptitudes to devise, create, shape, transform and contribute with all that practical knowledge, from minimizing a problem to being able to solve it completely.

Although it has not been an easy task for teachers of online or virtual careers, it has been a real challenge, trial and error before a new and unknown methodology that involved time, effort and dedication to know it and bring it to the classroom, to learn by doing together with the students, to be attentive to the questions and answer them; it can be said that currently, many fruits are being collected in countless training centers around the world, thanks to the commitment, active, responsible and committed participation of teachers and students as a whole.

The importance of incorporating the arts to science, technology, engineering and mathematics, as the initial disciplines of this educational methodology, has been decisive and vital, according to the authors, because human beings need to be inspired and motivated to carry out research that generates knowledge based on science, that contributes to engineering techniques, that facilitates the application of mathematics to the current reality, that promotes technological development; without which, most likely the results would be different, a smaller number of students with professional skills that the

labor market and society requires.

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