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The STEAM approach: Implementation and educational, social and economic consequences

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ABSTRACT
The integration of the arts and humanities into the core of curriculum along with the sciences and technological disciplines is an emerging issue in educational research. This article seeks to contribute to this research and curricular approach, for which we analyze the emergence of the STEAM movement, its implementation in class, and its social, economic, and educational consequences. The main conclusion reached is that, without ignoring the economic rationality in education, it is necessary to go further in order to embrace a more social and democratic conception of schooling, trying to take advantage of this historical moment to transform education toward a more humanistic approach–without neglecting the scientific facet–that offers a well-rounded education to new generations while, at the same time, responds to the social and economic demands of our current world.

KEYWORDS
STEM competences; STEAM competences; knowledge society; knowledge economy

Introduction

The movement that seeks to give new impetus to the development of Science, Technology, Engineering and Mathematics (STEM) began in the United States in the 1990s, sponsored by the *National Science Foundation*. After a few years of little social and educational impact (Friedman, 2005), the STEM movement has experienced a global expansion in the current century, especially in the 2010s, promoted by the *National Governor's Association* of that country. More specifically, in 2012 the project took a definitive leap into the educational sphere when President Obama decided to boost the recruitment of teachers in this field and thus address the shortage of students in these disciplines, compared to countries such as China, in an attempt to remain economically competitive by developing a national STEM identity. In fact, the comparison of the percentage of U.S. students in STEM degrees versus some other countries with powerful economies turns out to be very unfavorable for the former (Land, 2013).

In the educational field, this STEM identity responds to the need for citizens to understand the social impact of these disciplines, to be able to understand the advances and/or social contributions promoted by these disciplines, and to show interest in them (Perales & Aguilera, 2020). This is intended to generate a sense of belonging to a society in which the STEM disciplines would occupy an essential role that should be alien to ethnicity, gender and culture (Brickhouse et al., 2000; Carlone & Johnson, 2007; Polman & Miller, 2010).

Likewise, we find in the literature the term *STEM literacy*, coined by the *Washington STEM Study Group* in 2011, which appears connected to the concept of STEM identity (Zollman, 2012). This organization defines STEM literacy as the ability to identify and apply content from STEM knowledge areas to understand and solve problem situations that cannot be solved from a single disciplinary approach. The development of this new literacy would imply that each of the STEM disciplines includes a series of conceptual, procedural and attitudinal contents, so that if the mastery of each of them is necessary, so is the ability to recognize and appreciate the connections that exist between them. This integration of knowledge areas implies obtaining a final product different from the sum of the individual disciplines (Perales & Aguilera, 2020).

Given the characteristics of STEM education, active teaching methodologies seem the most suitable for

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implementing this teaching model. Thus, project-based learning (Domènech-Casal, 2019) or problem-based learning (Lou et al., 2011) have been used to carry out didactic proposals with a STEM approach (Martín-Páez et al., 2019).

Despite the exponential increase of initiatives in this educational movement worldwide, there are still reasonable doubts that everything published with this tag really responds to this acronym (Martín-Páez et al., 2019), or that STEM provides large doses of originality (Perales & Aguilera, 2020) compared, for example, to the chronologically earlier movement, called Science-Technology-Society (STS). Thus, several authors (e.g., Martín-Gordillo, 2020; Perales & Aguilera, 2020) criticize the STEM approach for its ambiguity, its dependence on the labor market, its appropriation of industry through STEM-tagged games, or the lack of consideration of ethical elements in its proposals. This questioning also extends to doubts about the existence of a STEM nature different from that of its component disciplines (Ortiz-Revilla et al., 2020).

In parallel to the development of the STEM approach, an important body of academic literature has been generated denouncing that focusing exclusively on STEM skills implies accepting the neoliberal economic rationality in education, which has led to a decline in the provision of artistic and humanistic education practically all over the world (e.g., Aróstegui, 2016, 2019; Burnard, 2010; Dalton, 2016; Woodford, 2018). The irruption of STEM has become a hegemonic discourse informing policy formation and educational practice (Ellison & Allen, 2018) which may hide economic interests in a globalized world compatible with neoliberal ideology (Bencze et al., 2018). Thus, as a result of the STEM approach, many students in various countries have been receiving scientific training at the expense of other unique human facets, especially the artistic, with consequent repercussions on students' learning in terms of subtracting them from a holistic view of the world.

Starting from this setting about what STEM is, in this article we discuss the need to consolidate the STEAM movement in education, where the A of arts plays a central role in the redefinition of school curricula. To do so, we will start with a description of the status of STEAM from STEM, then we will show some examples of STEAM projects, continuing with a reflection on the role of STEAM in a technified world that may be forgetting some fundamental objectives of education. We will conclude by suggesting the need to establish a research agenda that tries to fill the gaps that, in our opinion, still exist in order to give STEAM a relevant status in the educational future of young people.

What is STEAM?

Recently, the academic community has begun to show interest in encouraging and closely articulating the humanities with the sciences and technologies, as one of the keys to human development (e.g., Katz-Buonincontro, 2018). This search for integration responds to the need to offer new generations a well-rounded education, along with the social and economic uncertainty in the near future, where not only scientists and experts in science and technology will be needed, but also professionals in the arts, humanities and social sciences, to capture and understand the nuances and interpretations of human behavior (Hartley, 2017). As a consequence, the boundaries between transmitted knowledge inherited from increasingly specialized academic or university disciplines are beginning to blur—due to new connections and interactions among subjects because of their difuse limits–, with a perceived need to offer a more integrative education in line with economic and cultural globalization—that is, a disciplinary integration manifested as transdisciplinary, interdisciplinary, multi-disciplinary, cross-disciplinary, and arts-integration (Perignat & Katz-Buonincontro, 2019). One sign of this integration is the recent expansion of the acronym STEM to STEAM, by adding the A for the Arts (both visual and performing) and, by extension, the Humanities. The reasons why this integration arises are varied, although the main cause seems to be the approximation of the concept of creativity within STEM education (Katz-Buonincontro, 2018). Thus, a STEAM education could be defined as one that proposes an integrated teaching of scientific-technological, artistic and, in general, humanistic competencies, with integration understood in a progressive sense that goes from interdisciplinarity to transdisciplinarity.

A central issue that arises then is the status of A vis-à-vis STEM disciplines. The former can be understood not only as a domain of knowledge–that is, what the disciplines of the humanities and social sciences entail–, but also as different ways of knowing and experiencing the world through art forms, practices or even specific pedagogies that have to be part, not only of education, but of society in general–economy included. For Peppler and Wohlwend (2018) the inclusion of A in STEM implies a mutual enrichment as, on the one hand, artists can expand their creative potential of design through computational flexibility and versatility (referred in this case only to the T of STEM). On the other hand, the inclusion of A in STEM would have proven to be equally transformative as it not only generates new content knowledge. It also invites participation from populations historically underrepresented in STEM fields. This inclusion of the arts encompassed in STEAM also entails a reconsideration of the epistemology of A as opposed to those of STEM, which, at least, should incorporate a divergent conception of knowledge that goes beyond the conceptions of a reductionist science and where the recognition of uncertainty and the need to apply multi- and interdisciplinary approaches to the production of knowledge is contemplated (Colucci-Gray et al., 2019), as well as that of an arts education developed in "silos" and independent from the rest of the curriculum (Korsyn, 2003).

The A/STEM relationships have been represented by Mejías et al. (2020) around a dual axis: pedagogical-nonpedagogical and mutually instrumental-unilateral (Figure 1).

The objectives of STEAM education thus broaden its scope of action in a range that extends from the promotion of scientific-technological vocations to the acquisition of basic competencies and skills to meet the challenges of the future, summarized in the 4 Cs that appear in the 2030 Agenda: Creativity, Communication, Critical Thinking, and Collaboration (Tesconi & de Aymerich, 2020). To this, the acquisition of problem-solving skills and interest in STEAM will have to be added (Li & Wong, 2020). In this sense, the "A" would be providing science and technology education with new perspectives to represent reality through different and enriching languages. In this regard, Land (2013) speaks of traditional STEM degrees focus on convergent skills whereas Art degrees focus on divergent skills. An STEAM approach can contribute to overcome such simplified and disputable split.

More specifically, Kim and Kim (2016) categorized STEAM teaching competencies as follows: cognitive ability in subjects (understanding and using convergent knowledge); advanced thinking ability (creativity, problem-solving ability, critical thinking ability, ability to use information, and decision-making ability); ability to contribute to the community (ability to communicate, ability to engage in social relationships, and ability to cooperate); and individual emotional ability (self-respect, positive emotion, consideration, and civil awareness). In this regard Perignat and Katz-Buonincontro (2019) emphasize the need to "overlook the key aspects of arts education which include critique, self-expression, and conveying meaning. Both the critique process and the concept of conveying meaning through self-expression are hallmark characteristics of arts education which have shown to improve students' verbal and non-verbal communication skills, openness to others' perceptions, understanding of sociocultural dynamics, and self-understanding through reflection of their own experiences and emotions" (p. 41). The intrinsic motivation that the addition of A can provide, such as the enjoyment of the arts (music, painting,

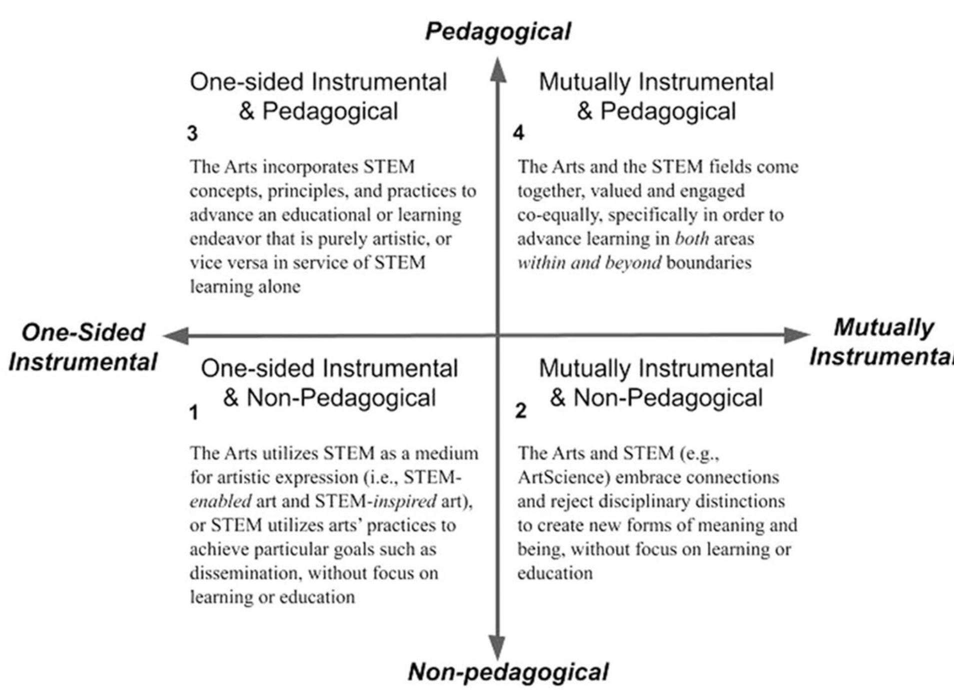

Figure 1. Possible relationships between the Arts and STEM. Source: Mejías et al. (2020, p. 12).

literature…) can neither be forgotten. As we observe, the STEAM approach can help to overcome the perennial debate about arts education either as an educational means or as an end itself by passing from a content-centered curriculum to another student' centered (Aróstegui & Kyakuwa, 2021).

Implementation of STEAM education

The inclusion of STEAM in the current educational agenda–either because of its recentness or for other structural reasons, such as the adaptation of school logistics or teacher training (Kim & Kim, 2016)—has not been translated into initiatives contrasted in quality and quantity. Thus, the literature review conducted by Perignat and Katz-Buonincontro (2019) showed an overall lack of reported learning outcomes in the areas of creativity, problem-solving, and arts education.

At the same time, experiences carried out show that STEAM makes children more active and capable of taking initiatives with their own knowledge, being able to increase their self-confidence (Wahyuningsih et al., 2020). To achieve this, Kim and Kim (2016) establish situation, creative design, and emotional touch as the learning criteria for a STEAM education. The situation is generated by learning to concretely feel the need to solve problems, while the creative design encourages students to find a way to solve them by themselves, and the emotional touch generates students' enthusiasm to challenge new problems through interest, motivation, and the joy of success.

Some specific initiatives include: visiting museums, hands-on work, conducting especially fun and/or online experiments, reading interactive books, gamification, simulation and video creation (Li & Wong, 2020), as well as using drama to model or create rhyming poems and songs to memorize information (Colucci-Gray et al., 2019). In particular, gamification as a process of converting non-game educational content and processes into game-like educational content and processes is gaining traction (Boytchev & Boytcheva, 2020).

Examples of noteworthy STEAM implementation projects are:

- Global Science Opera. Each year Scientix, the science education network in Europe (www.scientix.eu), launches its STEAM proposal for the production of a science opera with a specific theme. Several schools from different countries around the world create their two and a half minute scenes (libretto, music, set, costumes…), coordinated in pairs. Afterwards, they are jointly modeled from the central headquarters and premiered worldwide via the Internet. In addition, the groups carry out metacognitive activities on the proposed theme, such as outings to scientific institutions or museums, video chats among the participants, and even proposals for inquiry or design thinking (Tesconi & de Aymerich, 2020).
- The UK CREATIONS projects, "The Imagineerium" Sonic Pi, among others, encourage a partnership approach between teachers, artists and science experts to promote a more holistic understanding of science through art and vice versa. Drawing on diverse art forms such as dance, opera, visual arts, sound and theater, among others, students have the opportunity to engage scientifically with traditional approaches to problem solving, digital creation and design.
- In the United States, Costantino (2018) alludes to a project with art and natural history objects developed in collaboration with RISD's Lab, Museum, and Academic Affairs, where in a transdisciplinary way students explore abstract concepts through shared and unique forms of inquiry in science, art, and design, providing them with learning through multiple ways of approaching a problem.
- GetWet is a project related to a water pumping station at a heritage site, engage students' imaginations about real-life contexts in which scientists and technological developments are closely related to community life, connecting to science education related to socio-environmental issues and social-ecological justice (Colucci-Gray et al., 2019).

Other experiences described in the literature maintain a very varied nature: the use of electronic textiles to integrate STEM with A (Peppler, 2013), teacher training through case studies (Henriksen, 2014) or intensive professional development courses (Herro et al., 2017) and electronic platforms to support teachers and students (Soroko et al., 2020), among others.[1]

The role of STEAM in today's society

From what has been said so far, it is clear that it is possible to carry out scientific, artistic and humanistic learning that promotes both the key and the transversal competencies of curriculum at different levels.

The idea, however, is not completely new, having historical precedents such as those of the Renaissance, with a more global conception of culture and blurred disciplinary boundaries. Figures such as Leonardo da Vinci are paradigmatic in this regard but also later on, the integral formation of various historical figures has helped to make singular discoveries that would not have been possible from a purely disciplinary perspective. Thus, Harold Kroto, Nobel Prize winner in Chemistry for identifying the halotropic form of C60 (fullerene) from his fondness for Buckminster Fuller's architecture, inspired by a soccer ball, designed stable domes of pentagons and hexagons (Tesconi & de Aymerich, 2020). And the composer Iannis Xenakis, trained as an architect, applied physical and mathematical principles in his works and in his stochastic music (Xenakis, 2001).

As far as education is concerned, the first precedent for integrating science and the arts into the curriculum dates back to the Middle Ages, when the trivium (comprising grammar, dialectics and rhetoric) and the quadrivium (arithmetic, geometry, astronomy and music) were adopted as educational curricula. More recently, we have the lecture delivered by Charles Percy Snow in 1959 under the title "The Two Cultures" (Snow, 1959), in which he advocated precisely the crossbreeding between the sciences and the humanities and claimed that the lack of interdisciplinarity constituted one of the main drawbacks for the resolution of world problems.

At present we find, however, that before assessing the role that STEAM competencies can play within the curriculum, given the versatility of this acronym and its origins, there should be a prior debate on whether education should focus on meeting the needs of the global economy and thus excel in preparing future producers and consumers of material goods and knowledge, or promote a critique of socialization practices, such as schooling, and revisit the role of students as human subjects, in a continuous relationship with others and the natural world (Colucci-Gray et al., 2019).

If we assume that education should train for both economic and citizenship, then we must ask: (1) whether schools should change to offer STEAM-integrated teaching; (2) how teacher training should change if STEAM teaching becomes the norm; and (3) what research in this regard should be prioritized. If, on the contrary, in order to integrate the Arts as part of a STEAM-based curriculum we maintain the neoliberal economic agenda in schools, we run the risk that they will lose their essence, i.e., esthetics and emotion, and end up becoming a subsidiary tool to that part of the curriculum that has always been considered 'core' along with the area of mother language: the science subjects. If this were the inclusion of the Arts in STEM, we would still be doing the same thing we used to do in schools until now, but varnished with the fashionable term STEAM.

The question, then, is not only how to incorporate and articulate STEAM projects in school classrooms, but mainly for what purposes. The usual answer given from an economist perspective is that STEM subjects (without the A) are key to the development of the workforce of the future, due to the characteristics of the current capitalist model based on the production and transmission of knowledge: the so-called "knowledge economy." For example, a report by the *IESE Business School* at the University of Navarre, Spain, states that 72% of large Spanish companies find it difficult to fill the jobs they offer in Science and Technology, which could indicate an imbalance between the training students receive in schools and the needs of the labor market (Canals et al., 2019). But if we put these data in context, this answer about the STEM and the workforce of the future is not sufficient. Thus, in a report prepared by the U.S. Congress (Sargent, 2017), it is mentioned that "6.9 million people were employed as scientists and engineers, representing 4.9% of total employment in that country" (p. 6). And in Europe, the average rate of people working in technology in 2019 is 3.9% (Eurostat, 2020). Therefore, it cannot be considered that studying scientific-technological careers can solve the problem of youth unemployment; it is true that these data also indicate that there are not enough graduates in scientific studies, so probably the percentage rate in technical work will increase more or less depending on the technological development of the country, but they also say that the vast majority of the population will never work in this sector. The consequences for the development of the curriculum in relation to the labor market are clear: we need science and technology, but this is no guarantee of professional success, which is why, also from an economic perspective, other competencies must be incorporated into the core curriculum (A in our case). It also shows the need to work on competencies globally and without prioritizing some over others.

An education in which STEM disciplines are prioritized under the pretext that they are fundamental to the knowledge economy is not sustainable. In addition to the obvious fact that the human being has to be developed as a whole, going on the economic argument, the education system cannot continue to prioritize technical skills when any professional and research field can change in a very short period of time. Thus, Gianmarco et al. (2020) argue that the future of learning and work is social and emotional rather than technical, as employers increasingly demand human skills, such as social and emotional intelligence, collaboration, creativity, intercultural competencies, relationship building, resilience, and adaptability, which places new demands on our skills training systems, they argue.

Preparing for the knowledge society and the knowledge economy: the digital revolution

Arguments just discussed show the current need for a well-rounded education in which scientific and humanistic competencies are developed in an integrated manner. But this need is going further. An analysis by the Organization for Economic Co-operation and Development (OECD) (2018) has estimated that about 14% of jobs across the OECD area are at risk of automation, while another 32% are likely to see significant changes. And this is just the average, with the risk varying from 5.7% in Norway to 33.6% in Slovakia, clearly depending on the level of technological and digital development in each country. Robotization affects not only routine jobs but also financial, medical, accounting and many other jobs that require much more knowledge and expertise. But this does not necessarily imply a catastrophe for the workforce in the near future; in fact, the World Economic Forum (2020) predicts that 97 million emerging jobs will be created in the world in 2025. This data, compared to the 85 million that will be lost, arises an expected net job growth.

What these data also say, then, is that technology will drastically change the face of work (Oppenheimer, 2019). This robotization process, far from stalling as a result of the current COVID-19 pandemic and the ensuing economic recession, has only accelerated, with half of all jobs expected to be shared between robots and humans by 2025 (World Economic Forum, 2020), which could result in increased inequality. The digital revolution in which we are already living is far from over and promises a transformation of the labor market where many jobs are at risk, and the education system has to prepare for what is to come, without knowing exactly what it will be like, hence the need to develop transversal rather than key competencies. In fact, a high percentage of employers estimate that creativity and innovation will play a determining role in the future for future graduates (Allina, 2018).

This digital revolution forces us to prepare students to solve large-scale human problems that are not only technical, but fundamentally ethical. Educators, citizens, and students themselves need to broaden, not narrow, their futures to the technical and economic. Hartley (2017) asserted that we need technical experts, but we also need people who understand the nuances and interpretations of human behavior. If we do not, we take the risk of experts becoming the regulators of the social realm, i.e., of democracy becoming technocracy. To counteract this, we need to create spaces for social debate, in which education occupies a preeminent place, around at least the five areas set out in the Saragossa Declaration[2] on the development of artificial intelligence and its social implications: (1) the development of socially and environmentally responsible technologies; (2) traceability and verifiability of algorithms; (3) explainable technologies if fundamental rights are at stake; (4) development teams that integrate scientific and humanistic knowledge; and (5) codes of ethics of social responsibility for professionals and companies. As we can see, the demands of the new digital world, which is still expanding, go beyond economic and technological aspects; they are social and, therefore, essentially ethical, and the response from the educational system involves, among other aspects, STEAM curricula and teaching methodologies that integrate scientific and humanistic aspects.

It is interesting to note in this regard how many business companies are governed by managers with a degree in Humanities. This is the case of Slack, Alibaba, YouTube and Airbnb, whose presidents have a degree in Philosophy, English Philology, History and Literature, and Fine Arts, respectively. In fact, STEM competency appears in eighth place in a list of ideal skills that the president of Google would have to have (Davidson, 2017). There seems, then, to be a tendency even in the business world to promote and closely articulate the humanities with science and technology as one of the keys to human development that corresponds to the needs of a society that cannot be based on economic justification alone. As Morson and Schapiro (2017) stated, economics tends to ignore three things: the effect of culture on decision making, the usefulness of history in explaining people's actions, and the ethical implications of what we do. Even if economics could, education cannot ignore any of these.

Final considerations

Throughout these pages we have dealt with STEAM education from a double perspective: first, starting from an already established STEM education, we discuss what a STEAM education integrated with the arts is and could be like; second, we address the consequences that an education thus conceived has for the economy, the individual and society, highlighting the need from each of these three areas the need to train in the humanistic field, without forgetting the scientific, to provide a well-rounded education that responds to the needs of our world at all levels, including the economic one. We follow this twofold approach because we contend, alongside with many other authors (e.g., Kołczyńska, 2020; Rusinek & Aróstegui, 2015), that education holds both technical and political issues that we cannot ignore, hence the need for delineating "a policy thought as a key element of the education and professional life of any teacher" (Schmidt, 2015, p. 47).

Thus, we observe how an awareness to humanize technology is being generated, especially that which has to do with the use and development of the digital universe and whose high point is artificial intelligence. It would be a matter of injecting ethics and social justice to counteract the automatism and lack of counterweights in the unstoppable technological development that is calling into question the traditional model of democracy. This is what has come to be called "Technological Humanism," already claimed by Laurel (1998) as opposed to a dehumanized technology.

At the educational level, the development of STEAM-based curricula that go beyond the neoliberal agenda and promote democracy, critical thinking and the integral development of human beings is an alternative for the needs and demands of our current and future society, and also for our schools. Despite the consensus that seems to exist on the convenience and advantages of incorporating A to STEM, we cannot ignore the possibility of facing another "educational fad" or the difficulties that this entails. Challenges for the implementation of STEAM in the different educational stages are many. Some of them have to do with the design of educational programs with a different weight in the curricula between Science and Humanities, also with the design of specific activities from kindergarten or primary school to university degrees with this profile. This leads, first, to the need for teacher training in STEAM both in their initial and lifelong education, which is not easy considering the different nature of the disciplines involved, but which requires a profound transformation of the teacher education programmes in search for integration of science, arts and humanities at large. There are already successful experiences of STEAM integration such as in the case of South Korea (Kim & Bolger, 2017) that could pave the way for other countries that are already promoting various types of STEAM degrees such as the United States (Dell'Erba, 2019) or Australia (Hogan & Down, 2015). Second, it also leads to conclude that STEAM teaching is not a passing fad but, rather, an emerging area at both the curricular and research levels that is here to stay. However, we must be realistic about the actual scope of STEAM at present, given its weaknesses in terms of its very same definition, scarcity of contrasted experiences, and variability in the degree of A integration (Perignat & Katz-Buonincontro, 2019). To move forward, a policy setting must be established, to which this article aims to contribute.

As the cyberpunk author William Gibson said,[3] "the future is already here and it is not equally distributed." From our point of view a STEAM education is one possible answer that contributes to educate in that future that is already present and ensure that it reaches all citizens.

Notes

1. A compilation of STEAM experiences can be found at https://www.pinterest.es/pin/248190629443814739/
2. https://www.fundacionzcc.org/estaticos/upload/0/001/1910.pdf
3. https://en.wikiquote.org/wiki/William_Gibson

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