education sciences

Review

STEM vs. STEAM Education and Student Creativity: A Systematic Literature Review

David Aguilera [1] and Jairo Ortiz-Revilla [2,*]

1 Department of Science Education, University of Granada, 18071 Granada, Spain; davidaguilera@ugr.es
2 Department of Specific Didactics, University of Burgos, 09001 Burgos, Spain
* Correspondence: jortizr@ubu.es

Abstract: STEM (science, technology, engineering and mathematics) is an educational approach that is now accompanied by the STEAM (STEM + Arts) variant. Both educational approaches seek to renew the scientific literacy of younger generations, and, with the inclusion of the arts, student creativity is described as a key skill that must receive special attention. A review is therefore presented here of empirical STEM and STEAM-based educational interventions so as to determine their potential to develop student creativity. A systematic search of papers over one decade, 2010–2020, found 14 didactic interventions on the Web of Science and Scopus databases for analysis within the review process. The analysis suggested that: (1) the interventions based both on STEM and STEAM have multiple and even contradictory forms, both in theory and in practice; (2) there appears to be a preference among researchers for the Likert-type test to evaluate creativity; and (3) both educational approaches show evidence of positive effects on student creativity. In the light of the principal findings, it was concluded that arguing for the implementation of STEAM education over STEM education, with a view to developing or promoting student creativity, is not in agreement with the evidence from the empirical studies.

Keywords: STEM education; STEAM education; creativity; systematic review

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Citation: Aguilera, D.; Ortiz-Revilla, J. STEM vs. STEAM Education and Student Creativity: A Systematic Literature Review. *Educ. Sci.* **2021**, *11*, 331. https://doi.org/10.3390/educsci11070331

Academic Editor: Gary McPherson

Received: 16 April 2021
Accepted: 25 June 2021
Published: 2 July 2021

1. Introduction

Constant scientific-technological advances and rapid social change, all inter-related and with globalized impacts, require creative thought as an essential adaptative skill [1] and guarantee progress toward a more sustainable life [2].

Given the social context and drawing from the work of Craft [3], the extent to which the subject matter (thematic context) can limit or can add to the creativity of students from an educational point of view is a key question. Can creativity be instilled through physical education, mathematics, history, music or sciences? On these questions, Craft [3] concluded that: (1) the didactic strategy will be a determining factor in the development of the creative skills of the student; (2) despite the usual association between creativity and the artistic disciplines, all subjects from the study plan have the capability of participating in the development of student creativity; (3) the organization of the study plan, as a function of its flexibility, will offer greater or fewer opportunities to stimulate student creativity; and, (4) teaching each discipline in an isolated manner could limit the creativity of students by discouraging thoughts on topics and questions that are beyond the scope of only one subject.

About disciplinary integration, Henriksen [4] affirmed that the interdisciplinary nature of STEM (science, technology, engineering and math), based on the integration of the four disciplinary domains, helped students to apply their knowledge from different perspectives to generate a solution to a complex problem (product). By doing so, STEM education will have sufficient potential to develop the creativity of the student. However, STEAM education includes an A for arts in the teaching–learning process and has emerged more recently as a variant of STEM education, having the purpose of, among others, improving the creativity of students (E–A) [5]. Following this strand of thought, there are scarce few studies that pick out the effects of STEM (or STEAM) education on student creativity. In this regard, Batdi, Talan and Semerci [6], taking advantage of a meta-analysis to determine the effect of STEM education on the academic performance of students, analyzed the impact of STEM approach on the affective and cognitive dimensions and student skill levels from a qualitative perspective. Although these authors identify a possible effect of STEM approach on students' creativity, they do not collect the reasons. Facing this scenario, our review has two principal objectives: on the one hand, to characterize those didactic interventions that purport to follow a STEM or STEAM educational approach and, on the other, to evaluate its effect on student creativity. The following questions summarize both objectives:

1. Through which STEM/STEAM conceptual approach were the didactic interventions prepared that are used to develop student creativity?
2. From which perspective was creativity evaluated, and which instruments were employed to do so?
3. What reasons do the authors identify to explain the effect of interventions based on STEM/STEAM approach on creativity?

1.1. Conceptual Approach toward STE(A)M Education

The term STEM education has on numerous occasions been described as ambiguous. The different conceptualizations of this emergent educational model are perhaps due to the (scientific, academic, educational and/or political) context in which it is used [7], the geographic place [8] and its scant theoretical grounding [9,10]. STEM education has, therefore, followed a complex didactic transformation, giving rise to various educational experiences. Although its theoretical commitment follows the same educational approach, substantial differences have emerged in practice [11].

Alongside the broad range of STEM educational definitions, some differing from another with regard to their meaning, is the principal sign of its early development. From a more conservative to a more innovative position, these four definitions provide evidence of the principal problem that STEM education presents (ambiguity):

- Its focus is ihe resolution of problems based on concepts and procedures from science and mathematics, which incorporate the strategies applied in engineering and the use of technology [12].
- It is an E–A approach that integrates two or more STEM areas and/or one or more curricular subjects [10].
- It is an approach that seeks to teach content from two or more STEM domains, framed within a real context, so as to connect the subject matter with the daily life of the student [13].
- It is a meta-discipline based on learning standards where the teaching has an integrated approach; the specific content of this discipline is not divided; and it uses dynamic and fluid instruction methods [14], a perspective that is also found in Zollman [15].

Perhaps the definition of STEM education proposed by Sanders [10] represents the most open model, as it includes the possibility of integrating the STEM domains with other curricular subjects (arts, language, history, etc.). This defining line was taken by various authors, among whom Land [16] and Maeda [17], who highlighted the positive points of integrating the arts in the STEM acronym (STEAM): (1) to unify convergent thinking (characteristic of STEM disciplines) and divergent thinking (habitual in artistic and humanist disciplines) in the resolution of real problems; (2) to create personal meaning; and (3) for self-motivation. However, STEAM education presented the same problem as its predecessor STEM: multiple meanings (some very different between each other) for the same signifier, in this case STEAM education. The following definitions reveal some signs of this problem:

- Yakman and Lee [18] defined STEAM education as the interpretation of science and technology through engineering and the arts (a century that covered the humanities was studied); all based on mathematical elements.
- Zamorano et al. [19] defined STEAM as the interdisciplinary integration of sciences, technology, engineering, the arts and mathematics for the resolution of the daily life problems of students.

Two different perspectives currently coexist: on the one hand, the current that has adopted STEM education and led the vanguard in the United States and Europe [20]; on the other hand, the one that defends the inclusion of the arts, referring to this approach in the educational system of South Korea [18]. Nevertheless, educational investigation has shown weaknesses with regard to the conceptualization of both STEM [7,9,11] and STEAM education [21,22].

1.2. Creativity and Its Development in the Workshop

The treatment of creativity dates back various decades and has often stimulated the interest of investigators researching psychology and education [23]. A research area that has been renewed and even extended to people shaping educational policies, business leaders and government agents [1]. It responds to the attributes of creativity in such a way that helping the younger generation to develop their creativity has been seen as one of the best ways of preparing students for an uncertain future [23] framed in the Digital era [24] so much so that promoting potential creativity within educational spheres has been converted into a priority objective that is yet to materialize [25]. In this sense, some authors have affirmed that schools "kill" creativity [26] and that current educational policies have, generally, resulted in some sort of "creaticide" [27]. Others, on the other hand, have highlighted that creativity is inherent to the nature of humankind, so much so that it cannot be destroyed, only applauded or undermined, increasing or diminishing the likelihood of an individual showing personal creative potential [25].

The majority of researchers have defined creativity on the basis of two key elements, which have remained unchanged over various decades, specifically from the 1950s and the pioneering works of Barron [28] and Stein [29]. The first concept is novelty or originality, in such a way that creativity must generate something new and different. In addition, the product should comply with certain specifications and criteria on utility in the situation for which it was designed. Both concepts are necessary to qualify something as creative [30] and are encompassed in the standard definition of creativity [31]. If something is not appropriate or original, then it cannot be considered creative. However, stressing something as original and appropriate is strongly linked to a particular social, cultural and historic context [32], in such a way that the products must comply with both requirements in more than one context [33]. Creativity could, therefore, be interpreted through a systemic approach, a consequence of the interaction of three systems: (1) the sociocultural system that contains symbolic rules; (2) the personal system that brings novelty in a symbolic sense; and (3) the system that area experts configure in which the creative process is framed (recognize, evaluate and validate the product) [34]. In this sense of interaction, Runco and Sakamoto [35] also informed us that this dimension of human behavior appeared to be influenced by a broad range of developmental, social and educational experiences, which made themselves known in different ways in a variety of dominions.

Another form of interpreting creativity is to center on its level of expression. In this sense, Beghetto and Kaufman [1] proposed the "fourth C" model, in which the following levels of creative expression are described:

- Mini-c or interpretative creativity (e.g., when a student solves a mathematical problem in a different way to the example given in class).
- Little-c or daily creativity (e.g., development of a local project to solve an overabundance of pine processionary caterpillars).
- Pro-C or creativity expert (e.g., the idea of the inverted classroom that Aaron Sams and Jonathan Bergmann, both teachers, have advanced).

- Big-C or legendary creativity (e.g., the educational approach that Maria Montessori first devised).

Finally, in accordance with Davies et al. [36], if the didactic and pedagogic actions of the teacher are to favor the development of the creative potential of students, then it must be in keeping with the following aspects: (1) grant freedom of use and displacement between spaces; (2) set aside sufficient time and avoid rushing into the development of the activities; (3) lay out and incorporate a broad range of educational resources; (4) design novel and stimulating tasks; (5) focus learning from a perspective of play, minimizing pressures and permitting a structured yet flexible and self-directed learning experience; (6) promote cooperative work, dialogue and respect; and (7) rely on the participation of external bodies and experts unconnected with the school (museums, research centers, etc.).

2. Methods

A systematic literature review is presented in this study, given that the selection of work has been done on the basis of clearly defined and explained criteria for inclusion [37]. In addition, the selection process was designed in accordance with the PRISMA Declaration [38].

2.1. Article Selection Procedure

The search was conducted during the first half of January 2021 on the databases of Web of Science from Clarivate Analytics (specifically, in its main collection) and Scopus from Elsevier. The search was restricted to the decade 2010–2020. The search terms were ST=("STEM education" OR "STEAM education") AND ST=(creativity). Then, the following criteria for inclusion (Figure 1) were applied to the search results:

1. Journal articles or congress communications (proceedings) written in either Spanish or English.
2. The terms "STEM/STEAM education" and "creativity" appear in the title, abstract or keywords.
3. They present an educational intervention embedded in formal education in which the development of the creativity of students is considered.
4. They use research instruments to evaluate the creativity of the participants.
5. They set out conclusions on the impact of STEM or STEAM education on creativity.

2.2. Data Extraction Procedure

The data were extracted in accordance with the following units of analysis: (1) definition of STEM or STEAM education; (2) instrument used to evaluate creativity; (3) type of creativity under evaluation; (4) effect of STEM/STEAM education on creativity; and (5) arguments that justify the effect of the intervention. Table 1 shows the sections of the documents associated with each unit of analysis and examples of the codification in use. Only data that explicitly appeared were extracted, using the code "Not specified" in cases where data had been omitted or were not sufficiently clear, in order to avoid data interpretation.

2.3. Description of the Articles under Analysis

Table 2 shows the principal characteristics of the 14 studies on educational interventions that were included in the systematic review: author(s) and year of publication, country, educational stage for which each educational intervention was designed and study design.

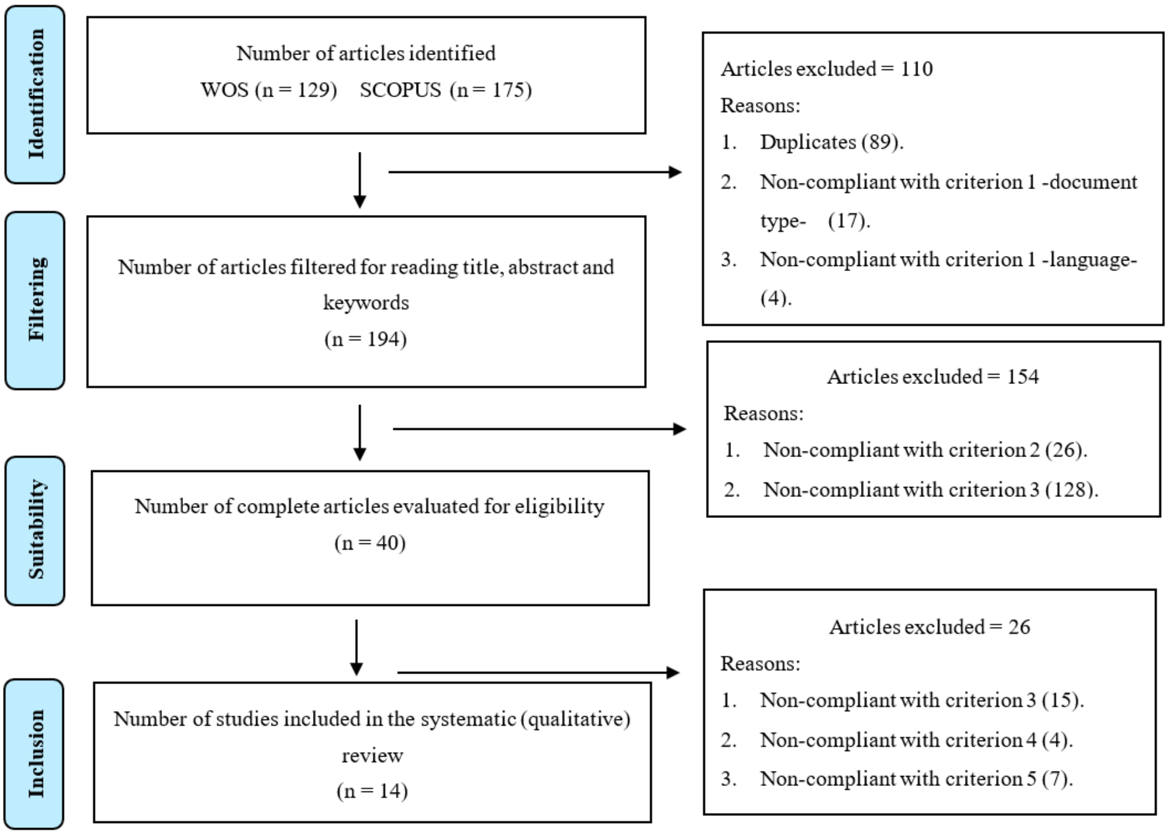

Figure 1. Flowchart of article selection procedure.

Table 1. Description of the units of analysis.

Unit of Analysis	Sections under Analysis	Coding
1. Definition of STEM/STEAM education	- Introduction - Theoretical framework	- Specific * - Nonspecific
2. Instrument	- Method (instruments)	e.g., TTCT (Torrance, 1966)
3. Evaluated creativity [a]	- Method (procedure)	- Creativity of the product - Creativity of the person - Creativity of the context - Creativity of the process
4. Effect	- Results - Discussion	- Positive * - Negative * - No effect *
5. Arguments	- Discussion - Conclusions	- Specific * - Nonspecific

* Extraction of the literal information. [a] In accordance with those established in Rogers (1954) [39].

Table 2. Article characteristics.

Authors	Year	Country	Educational Stage	Study Design
Oh, J., Lee, J. and Kim, J. [40]	2013	South Korea	Primary Education	Quasi-experimental
Engelman, S., Magerko, B., McKlin, T., Miller, M., Edwards, D. and Freeman, J. [41]	2017	United States	Secondary Education	Quasi-experimental
Öztürk, B. and Seçken, N. [42]	2017	Turkey	Secondary Education	Quasi-experimental
Kakarndee, N., Kudthalang, N. and Jansawang, N. [43]	2018	Thailand	Secondary Education	Quasi-experimental

Table 2. *Cont.*

Authors	Year	Country	Educational Stage	Study Design
Sattar-Rasul, M., Zahriman, N., Halim, L. and Abd-Rauf, R. [44]	2018	Malaysia	Secondary Education	Quasi-experimental
McKlin, T., Margerko, B., Lee, T., Wanzer, D., Edwards, D. and Freeman, J. [45]	2018	United States	Secondary Education	Case study
Ozkan, G. and Topsakal, U.U. [46]	2019	Turkey	Secondary Education	Quasi-experimental
Kuo, H.C., Tseng, Y.C. and Yang, Y.T.C. [47]	2019	Taiwan	University	Case study
Pinasa, S. and Srisook, L. [48]	2019	Thailand	Secondary Education	Pre-experimental
Conradty, C., Sotiriou, S.A. and Bogner, F.X. [49]	2020	Italy, Greece, United Kingdom and Malta	Primary and Secondary Education	Case study
Altan, E.B. and Tan, S. [50]	2020	Turkey	Secondary Education	Case study
Wannapiroon, N. and Petsangsri, S. [51]	2020	Thailand	University	Quasi-experimental
Conradty, C. and Bogner, F.X. [52]	2020	Greece and United Kingdom	Primary Education	Pre-experimental
Genek, S.E. and Küçük, Z.D. [53]	2020	Turkey	Primary Education	Pre-experimental

3. Results and Discussion

The results are presented below and are discussed in relation to the research questions that has been mentioned.

3.1. Conceptualizations of the STEM and STEAM Approaches

The results presented in Table 3 reflect the high degree of ambiguity that STEM education shows and STEAM education, likewise. Thus, we found no definition, neither of the STEM (see [47]) nor of the STEAM approach (see [45,49]), in 21.4% (n = 3) of the studies that were under analysis (n = 14), despite their indexing by title, abstract or keywords in this line of investigation. Aguilera (2020) [54] found similar results; he noted in his review of the literature that 33% of empirical studies that sought to improve student attitudes toward STEM disciplines never explained their conceptualization of STEM education, despite adopting this educational approach in their didactic interventions.

Table 3. Definitions of STEM and STEAM education from the studies.

Study	Definition
Oh et al. (2013) [40]	"Smart STEAM stands for Science, Technology, Engineering, Arts, Mathematics and means learning the fused knowledge of various fields." (p. 494)
Engelman et al. (2017) [41]	"The integration of STEM with the arts, called STEAM (science, technology, engineering, arts, and math), is gaining momentum as a method to increase student engagement in STEM topics through personal expression, aesthetic, and interdisciplinary projects." (p. 183)
Öztürk and Seçken (2017) [42]	"STEM education which is considered as one of the biggest educational movements of the late years is a multidisciplinary approach aimed at training students to integrate their disciplines in science, technology, engineering, and mathematics. In this approach, the four disciplines are not taught separately and with different subjects, but instead, together and at the same time in real life situations." (p. 604)
Kakarndee et al. (2018) [43]	"STEM education [. . .] is a curriculum based on the idea of educating students in four specific disciplines—science, technology, engineering and mathematics—in an interdisciplinary and applied approach. Rather than teach the four disciplines as separate and discrete subjects, STEM integrates them into a cohesive learning paradigm based on real-world applications." (p. 3)
Sattar-Rasul et al. (2018) [44]	"Sanders [10] defines STEM education as a process of integrating technology and engineering design concepts into teaching and learning of science and mathematics." (p. 82)
McKlin et al. (2018) [45]	Not specified.

Table 3. *Cont.*

Study	Definition
Ozkan and Topsakal (2019) [46]	"STEAM education comes to the forefront by conceptualizing in the form of (1) project-based learning, (2) technology in the context of creativity and design, (3) a multi-faceted approach to question a problem, (4) science, technology, engineering, art/human sciences and mathematics, all of which must be embedded in the problem (5) cooperative problem solving (Herro and Quigley 2016)." (p. 5)
Kuo et al. (2019) [47]	Not specified.
Pinasa and Srisook (2019) [48]	"Office of STEM education is Integration of integrated teaching across disciplines. Science (S), Technology (T), Engineering (E), and Mathematics (M), with the emphasis on nature and that interdisciplinary teaching approach that are supported by a large number of research." (p. 1)
Conradty et al. (2020) [49]	Not specified.
Altan and Tan (2020) [50]	"STEM educational approach defined as integrating two or more disciplines when solving real-life problems (Sanders 2009; Shaughnessy 2013; Smith and Karr-Kidwell 2000)." (pp. 3–4)
Wannapiroon and Petsangsri (2020) [51]	"STEAM Education is an educational approach that integrates science, technology, engineering, art, and mathematics in order to provide learners with creative skill, investigation skill, debate skill, critical thinking skill, and creativity and innovation [3]." (p. 1648)
Conradty and Bogner (2020) [52]	"The keyword "STEAM" refers to the integration of arts (A) and creativity in the classical STEM teaching (Science, Technology, Engineering and Mathematics). It is supposed to enrich science classrooms with creative interventions and by that way to counteract the low reputation of science teaching as abstract, difficult or even boring (Bennett & Hogarth, 2009; Henriksen, 2014)." (p. 1)
Genek and Küçük (2020) [53]	"The integrative approach to STEM education involves integration of at least two STEM disciplines by taking the interests and experiences of both students and the teacher into account while maintaining the central focus of the discipline taught (Çorlu, Capraro, & Çorlu, 2015)." (p. 1715)

Following this line of thought, Kakarndee et al. (2018) [43], Sattar-Rasul et al. (2018) [44] and Pinasa and Srisook (2019) [48] expressed a conception of STEM education in which the four disciplines are integrated, but their proposals appeared not to present the degree of integration adopted in theoretical works. As things stand, it has been impossible to confirm, in an objective way, the integration of the four STEM dominions in their educational interventions, as only scientific topics are explained, such as "force and movement" [43] and "energy" [44] and robotic activities [48]. Martín-Páez et al. (2019) had previously addressed this problem [11] through the identification of 30% of the didactic interventions that, despite their declared status as interventions adhering to the STEM approach at a theoretical level, had not adapted their practices accordingly.

We also found the work of Wannapiroon and Petsangsri (2020) [51], who defined STEAM education as a holistic educational approach that integrates the contents of the five domains of the acronym. However, those authors provided no explanation of the contents covered during their didactic intervention. From an objective viewpoint, it was therefore impossible to value the theoretical-practical consistency of that study. In turn, Oh et al. (2013) [40], considering the STEAM approach as the fusion of various fields, designed a program based solely on scientific content. Conradty and Bogner (2020) [52] also reported something similar in their study, as its design was focused on science classes, although only one scientific topic was named: "particle physics".

Öztürk and Seçken (2017) [42], in their holistic view of STEM education, developed a constructivist design approach that encompassed the four disciplines; Altan and Tan (2020) [50], who ascribed to the definition of Sanders (2009) [10], designed various projects based on the STEM approach in which the STEM disciplines were integrated in various ways (ST, STM or SE); and Genek and Küçük (2020) [53], considering that STEM education implies the integration of at least two of its disciplines, designed a program around four topics, each centered on one of the STEM disciplines.

Up until the present, studies have been published in which some indefinition exists around the concepts of STEM and STEAM education. Some studies appear to present contradictions between theory and practice; others employ the same signifier (STEM or STEAM education) but attach different meanings to each one. There are three different conceptualizations of STEAM education in the literature: (1) STEAM as integrated teaching of art and technology; (2) STEAM as the integration of art and sciences; and (3) STEAM as the integration of the five disciplines. These conceptualizations, from a theoretical perspective, are shown in Table 3 and, from a practical perspective, are exemplified in the following literal excerpts:

> "EarSketch is an integrated STEAM programming environment and curriculum that teaches elements of computing and sample-based music composition (i.e., composition using musical beats, samples, and effects) in an effort to engage a diverse population of students. [. . .] EarSketch fosters a learning environment that is both personally meaningful and of industrial relevance in terms of its STEM component (computing) and its artistic domain (music remixing)." [41] (p. 183)

> "The Creations project was set up to overcome this development. In Creations, a project funded by the European Union, 16 partners from ten European countries developed creative approaches based on art for an engaging science classroom. It breaks new ground to increase young people's interest in science, particularly by supporting the link between science and creativity." [49] (p. 4)

> "Thus, this study adopted a science and art-based approach by teaching the science topics. The technology was accessed through the use of tablet computers. Tablet computers are among the multi-sensory tools employed in STEAM education. The add-on applications on the tablet computer screen or tactile display stimulates sensory interaction (Taljaard 2016). The engineering field includes the design process (Charyton 2015). The mathematics field is included in the calculations of the STEAM design." [46] (p. 11)

3.2. *Type of Creativity Evaluated and Instruments Employed*

In accordance with Rogers (1954) [39], creativity can be evaluated through:

1. The process. This is attending to the creative process or, what is the same, to the procedures (actions) that the individual develops.
2. The context. Environmental factors that act as promoters or limiters of creativity are evaluated.
3. Person. The creativity capacity of the individual (cognitive abilities and perceptions of his creative skills) is assessed using test or questionnaires.
4. The product. Attention is paid to those characteristics of the results obtained (an essay, a drawing, a model, . . .) that show originality and creative potential.

Table 4 shows how the attention of the authors usually turns to the creative skills of the students (n = 13; 92.8%). Looking deeper at the different perspectives toward the evaluation of creativity, we found that Engelman et al. (2017) [41], Öztürk and Seçken (2017) [42], McKlin et al. (2018) [45] and Conradty and Bogner (2020) [52] all paid attention to both the creative potential of pupils and the environment/ learning context, while Altan and Tan (2020) [50] centered on analyzing the creativity evident in the product that the students had created.

Table 4. Types of creativity evaluated and associated instruments.

Study	Creativity Evaluated	Instrument
Oh et al. (2013) [40]	Creativity of the person	Torrance's TTCT Creativity Test
Engelman et al. (2017) [41]	Creativity of the person Creativity of the context	Ad hoc questionnaire
Öztürk and Seçken (2017) [42]	Creativity of the person Creativity of the context	Ad hoc questionnaire
Kakarndee et al. (2018) [43]	Creativity of the person	Creative Thinking Ability Test (CTAT) (ad hoc)
Sattar-Rasul et al. (2018) [44]	Creativity of the person	Ad hoc questionnaire
McKlin et al. (2018) [45]	Creativity of the person Creativity of the context	Ad hoc questionnaire
Ozkan and Topsakal (2019) [46]	Creativity of the person	Torrance Verbal and Figural Creative Thinking Test (TTCT) (Torrance 1966) [55]
Kuo et al. (2019) [47]	Creativity of the person	Abbreviated Torrance Test for Adults (ATTA) (Chen 2006 cited in Kuo et al., 2019) [47]
Pinasa and Srisook (2019) [48]	Creativity of the person	Ad hoc Questionnaire
Conradty et al. (2020) [49]	Creativity of the person	Version adapted from CPAC (Cognitive Processes Associated with Creativity) (Conradty and Bogner 2018) [56]
Altan and Tan (2020) [50]	Creativity of the product	Ad hoc Rubric
Wannapiroon and Petsangsri (2020) [51]	Creativity of the person	Torrance Verbal and Figural Creative Thinking Test (TTCT) (Torrance 1966) [55]
Conradty and Bogner (2020) [52]	Creativity of the person; Creativity of the context	CPAC questionnaire (Miller and Dumford 2016) [57]
Genek and Küçük (2020) [53]	Creativity of the person	Turkish adaptation of Scientific Creativity Test SCT (Çeliker and Balım 2012) [58]

If we compare the approach adopted in the didactic interventions with the perspectives toward the evaluation of creativity, we can see that the potential creativity of the learning environment is usually considered in the interventions based on the STEAM educational approach, as well as personal creativity, (see [41,45,52]). On the contrary, it only occurred in one of the seven interventions based on STEM education (see [42]). This consideration of creativity might respond to the fact of having integrated artistic disciplines together with the other STEM domains, in so far as various authors have expressed the advantages of the arts to generate a favorable classroom climate for the development of student creativity. The main reasons behind the argument are that it can: (1) favor social interaction, reduce stress, generate attraction and interest [59] and (2) promote positive emotions [60]. On the contrary, the didactic proposal of Altan and Tan (2020) [50], based on STEM education, was centered on product creativity. A decision that has an explanation in the nature of the STEM [61] disciplines. Accordingly, Ferreira-Gauchía et al. (2012) [62] highlighted the orientation of technology toward proper functional operation of the technological elements that were created in a continuous way. Equally, Moore et al. (2015) [63] remarked that the principal characteristic of engineering was the design and the production of different types of products and artefacts.

Finally, with respect to the investigation instruments associated with the evaluation of creativity, two relevant matters may be identified: the questionnaire was the most widely used instrument (n = 13; 92.8%), and the investigative instruments are usually prepared ad hoc for the study in question (n = 7; 50%), reporting scant data on its validation process and analysis of reliability.

3.3. Effect of the STE(A)M Interventions on Creativity

Tables 5 and 6 present the evaluations of the effects of STEM education and STEAM education, respectively, on creativity, and the elements that the authors understood as causing the effect as a result of the proposals.

Table 5. Effect of STEM education on creativity and reasons.

Study	ES * (d)	Effect	Reasons
Öztürk and Seçken (2017) [42]	[a]	Positive	• Raise the profile of the utility of the contents for daily life.
Kakarndee et al. (2018) [43]	6.97	Positive	• Promote cooperative work and an agreeable classroom atmosphere. • Flexibilize the teaching–learning process. • Disciplinary integration.
Sattar-Rasul et al. (2018) [44]	[a]	Positive	• Disciplinary integration.
Kuo et al. (2019) [47]	1.26	Positive	• Use project-based learning.
Pinasa and Srisook (2019) [48]	[a]	Positive	• Use project-based learning.
Altan and Tan (2020) [50]	-	Positive	• Use design-based learning.
Genek and Küçük (2020) [53]	-	Positive	• Variety of contents and skills covered.

* Effect sizes (Cohen's d); [a] insufficient statistical data available; "-" not applicable.

Table 6. Effect of STEAM education on creativity and reasons.

Study	ES * (d)	Effect	Reasons
Oh et al. (2013) [40]	0.62	Positive	• Use of programming languages (scratch).
Engelman et al. (2017) [41]	0.74	Positive	• Disciplinary integration.
McKlin et al. (2018) [45]	1.23	Positive	• Disciplinary integration.
Ozkan and Topsakal (2019) [46]	0.56	Positive	• Resolve real problems. • Flexibilize the teaching–learning process
Conradty et al. (2020) [49]	[a]	Positive	• Employ inquiry-based learning. • Promote cooperative work.
Wannapiroon and Petsangsri (2020) [51]	[a]	Positive	• Gamify the teaching-learning process. • Promote cooperative work.
Conradty and Bogner (2020) [52]	[a]	Positive	• Teacher training.

* Effect sizes (Cohen's d); [a] insufficient statistical data available; "-" not applicable.

These results have to be treated with caution, in view of the theoretical–practical contradictions previously commented upon that are evident in the didactic interventions of Kakarndee et al. (2018) [43], Sattar-Rasul et al. (2018) [44], Pinasa and Srissok (2019) [48], Oh et al. (2013) [40] and Conradty and Bogner (2020) [52], as well as the omission of any conceptualization of the term STEM or STEAM education in the works of Kuo et al. (2019) [47], Conradty et al. (2020) [49] and McKlin et al. (2018) [45]. When we took those studies that showed some coherence between their theoretical stance and the practice of their STEM and STEAM proposals (see [41,42,46,50,53]), we found that both STEM education and STEAM education are capable of generating a positive effect on student creativity, which seems to be attributed to original and novel educational scenarios. This fact might on the whole respond to methods E–A associated with these educational approaches (n = 7; 50%) and disciplinary integration (n = 4; 28.5%); factors already highlighted in previous reviews, such as the one developed by Batdi et al. (2019) [6] and Aguilera (2020) [54]. In addition, given that creativity is closely related with talent, knowledge levels, skills, intrinsic motivation, personality and the social environment [64], those arguments related with cooperative work, the flexibility of the E–A process, treatment of skills, the resolution of real-life problems and their utility for daily life could positively impact the earlier aspects. In this sense, efforts are currently being made to broaden the vision of STEAM toward more holistic models that integrate, for example, content and foreign language learning (as is the case of the SELFIE project). Once again, the need to interpret these inferences with caution must be underlined, because, in addition to the previously proposed questions, we have identified studies that present contradictions between the conclusions expressed in their abstracts and the arguments of the articles (see [53]). On the contrary, others do not share all the results obtained, turning out to be incomprehensible to the reader (see [42]).

4. Conclusions

On the one hand, the didactic interventions that declared to have followed a STEM or a STEAM educational approach have been characterized in this study and, on the other, to evaluate its effect on the creativity of the students. In this way, we can conclude that:

1. Neither the STEM nor the STEAM educational approach enjoys the conceptual clarity for researchers, academics and/or teachers to design, implement and evaluate didactic interventions based on those educational approaches with a certain degree of similarity, in so far as the didactic and pedagogical principles are concerned (for example, the number of disciplines that they should integrate or the way they should be integrated).
2. Both the STEM and the STEAM educational interventions are centered on the creativity of the person, on the whole using Likert-type questionnaires. Nevertheless, STEAM education appears to lend greater attention to the context in which the E–A process was developed, whereas STEM education was proven to be of a more finalist nature, by centering the analysis on the products created by the students.
3. Both STEM and STEAM education generated positive effects on student creativity. However, the references upon which we relied in this review were too few and far between for us to certify with some rigor that the bonds of these educational approaches can promote the potential development of creativity within the student. Despite this lack of clarity, although the convenience of STEAM education, over and above STEM education, might appear clear, with a view to developing the creativity of students [5,52,56], it is an invalid argument.

In brief, this review of the literature has once again demonstrated that both STEM and STEAM education lack a clear conceptual framework with broad consensus within the scientific–educational community. In this sense, the possibilities of implementing this approach in practice are diminished, as well as the rigorous evaluation of its educational potential. In addition, it highlights an obligation upon the scientific community to increase the number of studies of an experimental nature in order to determine whether STEM and STEAM education have the capability to develop the creativity of students. With this study, we believe that we have provided relevant information contributing to the current analysis of STEM and STEAM educational approaches, both of which are in full expansion.

Author Contributions: Conceptualization, D.A. and J.O.-R.; methodology, D.A. and J.O.-R.; formal analysis, D.A. and J.O.-R.; literature review, D.A. and J.O.-R.; resources, D.A. and J.O.-R.; data curation, D.A. and J.O.-R.; writing—original draft preparation, D.A. and J.O.-R.; writing—review and editing, D.A. and J.O.-R.; supervision, D.A. and J.O.-R.; funding acquisition, D.A. and J.O.-R. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by Ministry of Science, Innovation and Universities (Spain) who finances the research project PROFESTEM (PGC2018-095765-B-I00) and by European Commission through project SELFIE (2020-1-ES01-KA201-081850).

Conflicts of Interest: The authors declare no conflict of interest.

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