Perceptions and Implementation of the STEAM Approach among Spanish Secondary School Teachers

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***Abstract*—Educational systems increasingly seek approaches that integrate scientific knowledge with creativity and interdisciplinary problem solving. In this context, the Science, Technology, Engineering, Arts, and Mathematics (STEAM) approach has emerged as a relevant pedagogical framework. However, its effective implementation depends largely on teachers' knowledge, perceptions, and classroom practices. This study examines teachers' knowledge, use, and appraisal of STEAM in Spain, as well as their willingness to receive training. A quantitative descriptive study was conducted using an online survey administered to 113 teachers in scientific and technological subjects. Descriptive statistics and non-parametric tests were applied. The results show moderate levels of knowledge and limited classroom implementation, although teachers who have applied STEAM report positive experiences. Significant differences were found according to gender, age, and teaching methodology, while no differences were observed by school type. Most participants also reported a strong interest in further professional development. These results suggest that strengthening teacher training is essential to support the effective adoption of STEAM in educational practice.**

***Keywords*—STEAM, learning, teaching methodology, teacher perceptions, teacher training, digital competence, educational innovation**

I. Introduction

Information and Communication Technologies (ICT) and Technologies for Learning and Knowledge (TAC) have become central elements of contemporary educational environments, particularly following the large-scale digitalization of teaching during the COVID-19 pandemic [1]. However, the integration of technology into classrooms does not automatically lead to meaningful learning outcomes. On the contrary, the rapid expansion of digital tools has reinforced the need for pedagogical approaches capable of fostering creativity, critical thinking, and higher-order cognitive skills. Within the context of the early stages of the Fourth Industrial Revolution, education systems face the challenge of preparing students—often described as "digital natives"—to address complex scientific and technological problems in increasingly digital and interdisciplinary environments [2].

In response to these challenges, current educational debates emphasize the importance of developing transversal competencies such as problem solving, innovation, adaptability, and analytical thinking. Previous research suggests that the presence of technologically equipped classrooms alone is insufficient to achieve these goals [3]. Rather, meaningful transformation requires methodological innovation capable of overcoming the traditional fragmentation of school curricula and the separation between theoretical knowledge and practical application. In this regard, active learning methods have gained increasing attention, as they place students at the center of the learning process and promote engagement, collaboration, and metacognitive development [4, 5].

Within this pedagogical shift, the Science, Technology, Engineering, Arts and Mathematics (STEAM) method has emerged as a multidisciplinary framework that integrates scientific and technological disciplines with the arts and humanities. Originally developed in the United States, STEAM has rapidly expanded worldwide as an educational response to the growing demand for interdisciplinary and innovation-oriented competencies in knowledge-based economies. However, the successful implementation of STEAM largely depends on teachers' preparedness to adopt new pedagogical strategies and integrate them into their teaching practices. Consequently, teacher digital competence and pedagogical readiness for STEAM have become central topics in educational research [6, 7].

Despite the increasing prominence of STEAM in educational policy and academic literature, empirical evidence regarding teachers' knowledge, implementation, and perceptions of this approach remains limited in several national contexts, including Spain. Moreover, many studies focus on conceptual or theoretical aspects of STEM/STEAM education, while fewer examine teachers' perceptions and use of these methodologies [8]. Therefore, understanding teachers' perspectives is essential for identifying barriers to STEAM implementation and for designing effective teacher training strategies.

This study contributes to the existing literature by providing an integrated analysis of teachers' knowledge, implementation, and perceptions of the STEAM approach in secondary education, within the Spanish context. Unlike previous studies that focus on isolated dimensions, this research combines these aspects with an examination of sociological and pedagogical variables, offering a more comprehensive understanding of the factors influencing STEAM adoption. Furthermore, by interpreting the findings through the Technological Pedagogical Content Knowledge (TPACK) framework, the study provides a more analytically grounded perspective on teacher preparedness and methodological integration. These contributions help to bridge the gap between theoretical frameworks and classroom practice, offering relevant insights for both research and educational policy.

II. Literature Review

Educational institutions are increasingly pressured by the rapid transformation of the Knowledge Society, which continuously introduces new expectations for teaching and learning. In secondary education, these expectations translate into the need to prepare students for a digitalized, global, and highly competitive environment. This challenge requires teachers to adopt new competencies and methodological strategies that integrate curricular areas, foster transversal skills, and support meaningful digitally mediated learning experiences [9].

A. From STEM to STEAM: Evolution toward Interdisciplinary Curricula

In Spain, methodological innovation in science and technology education has been strongly shaped by the STEM approach (Science, Technology, Engineering and Mathematics), which has become widely embedded in classroom practice and educational discourse [10]. Internationally, STEM began to consolidate as a recognizable educational movement in the 1990s [11], gaining increased policy relevance in the following decade [12]. Early STEM initiatives were often framed around strengthening scientific and technological training, frequently prioritizing technical knowledge and performance outcomes [13]. However, as STEM education expanded, concerns emerged regarding overly instrumental views of learning and the limited attention paid to creativity, communication, and human-centered design. In response, a growing body of scholarship advocated for broader interdisciplinary integration, emphasizing that the arts and humanities can play a structural role in scientific-technical learning by promoting creativity, contextual reasoning, and innovation [14]. This evolution contributed to the emergence and consolidation of STEAM, explicitly incorporating "Arts" as a means to enrich STEM education and support more holistic curricular integration [14].

B. Methodological Foundations and the Role of Digital Tools

Alongside curricular integration, research has examined the pedagogical mechanisms that can make STEAM approaches effective in practice. One influential strand links these methodologies to gamification and game-based strategies, particularly as digital technologies make interactive, inquiry-oriented learning experiences more feasible and scalable [15, 16]. As this line of work developed, STEM—and later STEAM—was increasingly associated with interdisciplinary learning designs that combine active participation with structured problem framing and iterative solution building [17]. Within this context, digital tools have been studied not merely as add-ons, but as enabling resources that can support core practices such as inquiry, argumentation, design, and communication. López *et al.* [18], for instance, emphasized the contribution of digital tools to the enactment of scientific, engineering, and mathematical practices in STEM learning environments. Over time, this evidence base has expanded, consistently indicating that integrated STEAM approaches can support learners in building connections across disciplines and constructing more coherent scientific-technical understandings [19–21].

C. Conceptual Clarification and Design Frameworks in STEM/STEAM

Despite its expansion, STEM has long been characterized by conceptual ambiguity. Early discussions highlighted that STEM could refer to a wide range of educational goals, instructional practices, and integration models [11], and the term has been repeatedly described as broad or insufficiently defined [22]. In recent years, however, systematic reviews and conceptual analyses have significantly advanced the field by clarifying the meaning of "integration" and by distinguishing between multidisciplinary and interdisciplinary models, as well as between activity-based and problem-driven implementations [23]. In parallel, didactic research has increasingly focused on how to operationalize STEAM in school contexts, documenting practical design principles and classroom constraints [24]. This line of work has converged toward definitions that conceptualize STEAM as educational frameworks in which scientific-technical (and, in STEAM, artistic/humanistic) domains are addressed through integrated learning experiences, with or without explicit connections to authentic real-world problems [25]. In addition, recent contributions have moved beyond definitions toward implementation guidance, providing structured components, phases, tensions, and evaluation criteria for designing higher-quality STEAM projects [26]. Together, these advances reflect a shift from conceptual debates to concerns about design quality, feasibility, and assessment.

D. Teacher Preparedness: TPACK, Professional Development, and Implementation Barriers

A central and recurrent finding across STEAM research is that successful implementation depends heavily on teacher preparedness. Building on the TPACK model [27], Fuentes and González [28] argued that effective STEAM teaching requires competence across content knowledge, pedagogical knowledge, and technological knowledge. However, this background can be further enriched by incorporating broader perspectives on pedagogical transformation and interdisciplinary learning. STEAM education is closely aligned with active learning paradigms, such as project-based learning and inquiry-based learning, which emphasize student-centered approaches and the integration of knowledge across disciplines. From this perspective, STEAM should be viewed not merely as a specific methodology, but more crucially, as a component of a broader transition toward flexible, competency-based, and interdisciplinary educational frameworks.

Nevertheless, it cannot be assumed that most secondary teachers have received training that is simultaneously strong in all TPACK domains or that fully prepares them for this broader pedagogical shift. Consequently, several authors stress the need to examine whether teacher education is sufficiently updated and aligned with current educational demands [29], particularly in scientific-technical subjects where methodological change can be especially demanding. In practice, teacher implementation is frequently constrained by barriers such as limited training, insufficient planning time, and uncertainty about how to design interdisciplinary learning experiences that remain both coherent and assessable [30]. These constraints highlight that the challenge of STEAM adoption is not only technical or curricular, but also deeply pedagogical and organizational.

Furthermore, previous research suggests that teachers' perceptions of innovative methodologies are strongly influenced by their prior experience with active learning strategies, their pedagogical beliefs, and their confidence in managing complex classroom dynamics [31, 32]. Therefore, the analysis of STEAM adoption benefits from considering not only technological and content-related competencies, as proposed by TPACK, but also teachers' pedagogical orientation and openness to methodological innovation [33]. By integrating these perspectives, STEAM implementation can be more accurately understood as part of a broader process of educational change, in which teacher readiness, institutional support, and pedagogical culture interact to facilitate or hinder the adoption of interdisciplinary approaches in secondary education.

E. Evidence on Teacher Perceptions and the Remaining Gap in Spain

Empirical work has also explored teachers' perceptions, showing that knowledge, appraisal, and willingness to implement STEAM can vary across sociological and demographic variables [34], including gender-related differences in perceptions and practices [35]. In addition, prior research indicates that experience and professional development engagement are linked to differences in teachers' confidence, classroom enactment, and attitudes toward integrated STEAM approaches [36, 37]. However, despite the international growth of this evidence base, studies focused specifically on Spanish secondary teachers remain comparatively limited, particularly those that simultaneously examine sociological variables (e.g., gender, age) and academic/contextual variables (e.g., school type and dominant teaching methodology). Addressing this gap is essential to better understand the actual status of STEAM implementation in Spain and to inform targeted professional development and policy measures.

III. MATERIALS AND METHODS

A. Design

This study follows a quantitative descriptive design based on the results of a survey administered to Spanish secondary school teachers in scientific-technical areas, focusing on their knowledge, use, and perceptions regarding STEAM implementation. Data were analyzed both globally and stratified according to respondents' gender, age range, school type (public, private, or state-funded private, commonly referred to in Spain as "concerted"), and most frequently used teaching methodology.

Regarding data analysis, several statistical tests were applied depending on the nature of the variables. Specifically, a test for comparing proportions across two or more samples was used for the item assessing teachers' willingness to receive training in STEAM. For the remaining items, the non-parametric Mann–Whitney or Kruskal–Wallis tests were used depending on the number of subgroups being compared. A significance level of 0.05 was adopted for all analyses. Non-parametric tests were selected because the Lilliefors normality test indicated that the assumption of normality could not be met for the response distributions. A chi-square test for goodness of fit was used to compare proportions in the responses related to training interest.

B. Participants and Variables

Participants were selected using a non-probabilistic convenience sampling strategy. The survey was distributed to secondary school teachers in scientific-technical areas from different regions of Spain through the authors' professional and academic social media networks. A total of 113 teachers voluntarily participated in the study. Their distribution across the independent variables is presented in Table 1.

Table 1. Independent variables, categories, and frequencies

Type	Variable	Categories	Proportion (%)
Sociological	Gender	Male	37%
		Female	63%
	Age range	Under 25	1%
		25–34	23%
		35–44	33%
		45–54	34%
		55 or older	9%
Academic	School type	Private	7%
		State-funded private (concerted)	23%
		Public	70%
	Teaching methodology (most frequent)	Lecture-based	12%
		Dynamics (debate, role-playing, etc.)	1%
		Lecture + dynamics	35%
		Lecture + active methodologies	49%
		Only active methodologies	3%

Four independent variables were considered: two sociological variables (gender and age range) and two academic variables (school type and dominant teaching methodology), as shown in Table 1. In Spain, "concerted" schools are privately managed institutions that receive public funding. The dependent variables and their corresponding measurement scales are presented in Table 2.

Table 2. Dependent variables and measurement scales

Dependent variable	Scale / Values
Knowledge level of STEAM	Likert 1–5 (1 = none; 2 = low; 3 = medium; 4 = high; 5 = expert)
Frequency of STEAM use in class	Likert 1–5 (1 = never; 2 = rarely; 3 = sometimes; 4 = often; 5 = almost always)
Appraisal of STEAM	Likert 1–5 (1 = very dissatisfied; 2 = dissatisfied; 3 = moderately satisfied; 4 = satisfied; 5 = very satisfied)
Willingness to receive STEAM training	Trichotomous (yes/no/maybe)

C. Instrument

Data was collected using an online questionnaire created with Google Forms and distributed throughout the 2023–2024 academic year. Participation was voluntary and anonymous, and no personally identifiable information was collected. Before completing the questionnaire, participants were informed about the purpose of the study and the use of the data for research purposes only. The questionnaire consisted of three Likert-type items (A, B, and C) rated on a five-point scale and one multiple-choice item (D), each corresponding to one of the dependent variables described in Table 2. The instrument was conceived as a concise tool aligned with the exploratory nature of the study, balancing the need to capture key dimensions of STEAM-related perceptions with the practical objective of ensuring a high response rate among participants. Therefore, while the questionnaire design was grounded in the research objectives and existing literature, it was not intended to function as a fully developed psychometric scale, but rather as an initial approximation to the constructs under analysis.

The psychometric properties of the instrument were assessed through complementary analyses of correlation, reliability, and preliminary construct validity.

First, Pearson correlation coefficients were calculated to examine inter-item associations and the relationship between each item and the overall survey score. For this purpose, the trichotomous dependent variable related to willingness to receive training was numerically coded as follows: 1 = No, 2 = Maybe, and 3 = Yes. As shown in Table 3, correlations among the items were moderate, while correlations between each item and the total score were high. All coefficients were statistically significant, supporting the internal coherence of the questionnaire.

Table 3. Pearson correlations among survey items and total score ($p < 0.05$)

Items	A	B	C	D	Total
A	1	0.5877*	0.5982*	0.5021*	0.8544*
B		1	0.6201*	0.5710*	0.8757*
C			1	0.6112*	0.8467*
D				1	0.8101*

Note: * indicates statistical significance at $p < 0.05$.

To further reinforce methodological transparency, internal consistency was examined using Cronbach's alpha. Considering the four survey items together, the instrument showed good reliability ($\alpha = 0.848$). In addition, when focusing specifically on the three Likert-type items related to knowledge, classroom implementation, and appraisal of STEAM, Cronbach's alpha remained acceptable ($\alpha = 0.819$), indicating satisfactory consistency for exploratory purposes. Given the concise structure of the questionnaire and its exploratory design, construct coherence was primarily assessed through inter-item correlations and internal consistency measures rather than through more complex psychometric validation procedures. In this regard, the statistically significant Pearson correlations observed among items, together with the reliability coefficients obtained, provide preliminary support for the internal coherence of the instrument. Taken together, these results support an acceptable level of reliability and consistency in relation to the exploratory objectives of the study. Nevertheless, due to the concise structure of the questionnaire and its descriptive purpose, the instrument should be interpreted as a preliminary approximation to the constructs analyzed rather than as a fully developed psychometric measurement scale.

D. Ethical Considerations

This study was conducted in accordance with the ethical standards established for research involving human participants. Ethical approval was granted by the Ethics Committee of the University of A Coruña, Spain (Approval code: 2022-021).

Informed consent was obtained from all participants prior to completing the survey. Participation was voluntary and anonymous, and no personal data that could identify participants were collected to guarantee confidentiality and data protection.

IV. Results

This section presents the results obtained from the statistical analysis of the survey responses. First, the descriptive statistics for the dependent variables are presented. Subsequently, the results are analyzed according to the independent variables considered in the study.

A. Descriptive Results

Table 4 presents the mean values and standard deviations for the three Likert-scale questions included in the survey. The results show that the level of knowledge about the STEAM approach and the frequency of its implementation in the classroom are relatively low, as both mean values are close to 2 on a five-point scale. However, the standard deviations, which are above 1 in both cases, indicate a considerable variability in the responses.

Table 4. Mean values and standard deviations for the three Likert-scale items

Item	Mean	SD
Knowledge level of the STEAM approach	2.15	1.06
Frequency of STEAM implementation	2.07	1.03
Appraisal of the STEAM approach	3.19	0.99

Approximately 65.5% of the respondents reported having applied the STEAM method in their classroom at least once, meaning that they did not select the response "never" for the question related to frequency of use. Among those teachers who have applied STEAM, the overall appraisal of their experience tends to be moderately positive. The mean value for the appraisal of the STEAM approach is above 3, suggesting that teachers who have experience with the methodology generally evaluate it favorably. In contrast to the previous variables, the standard deviation for this item is below 1, indicating a greater homogeneity in responses.

Table 5 presents the responses to the question regarding teachers' willingness to receive training in the STEAM approach. Nearly three quarters of the participants stated that they would like to receive such training, and the proportion of respondents answering either "yes" or "maybe" exceeds 95% of the sample. The chi-square test confirms that the proportion of affirmative responses is significantly higher than the others.

Table 5. Distribution of responses regarding willingness to receive STEAM training and results of the comparison of proportions test

Response	Percentage	Chi-square	df	*p*-value
Yes	71.68%			
No	4.42%	81.204	2	0.0000*
Maybe	23.89%			

Note: * indicates statistical significance at $p < 0.05$.

B. Gender Differences

Table 6 presents the results differentiated by gender. The data show that male teachers report higher levels of knowledge of the STEAM approach, use it more frequently in their classrooms, and provide slightly higher evaluations of the methodology.

The Mann–Whitney test indicates that the difference between male and female teachers is statistically significant for the knowledge variable, suggesting the existence of a gender gap in perceived knowledge of the STEAM approach. For the remaining variables—frequency of use and appraisal—no statistically significant differences were identified.

Table 6. Means, standard deviations, and Mann–Whitney test statistics for gender comparisons

Item	Men Mean	SD	Women Mean	SD	W	*p*-value
Knowledge level	2.5	1.2	1.94	0.9	1876	0.0171*
Frequency of implementation	2.14	1	2.03	1.1	1621	0.42
Appraisal of STEAM	3.32	1	3.11	1	705.5	0.2743

Note: * indicates statistical significance at $p < 0.05$.

Fig. 1 compares the mean values obtained by male and female participants with the overall mean values. As shown, male teachers consistently report higher values across all three variables, particularly in their perceived knowledge of the STEAM approach.

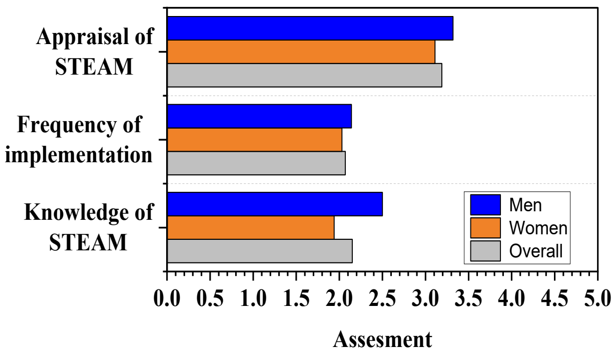

Fig. 1. Comparison of mean responses by gender and overall averages for the three Likert-scale items.

Table 7 shows the responses regarding willingness to receive training in STEAM differentiated by gender. In both groups, the proportion of teachers willing to receive training exceeds 95% when combining "yes" and "maybe" responses. The comparison of proportions test indicates that there are no statistically significant gender differences for this variable.

Table 7. Distribution of responses regarding training interest by gender

Gender	Response	Frequency	Percentage	Chi-square	df	*p*-value
Male	Yes	29	69.00%	0.2294	2	0.8916
	No	2	4.80%			
	Maybe	11	26.20%			
Female	Yes	52	73.20%			
	No	3	4.20%			
	Maybe	16	22.50%			

C. Age Differences

The results differentiated by age range are presented in Table 8. For the statistical analysis, the category of teachers under 25 years of age was excluded due to the presence of only one participant in that group.

Table 8. Means and standard deviations by age group

Item	25–34	SD	35–44	SD	45–54	SD	≥55	SD
Knowledge	2.42	1.1	2.05	1.2	2.15	1	1.9	0.9
Frequency	1.85	1.1	2.03	1	2.15	1	2.5	1.1
Appraisal	3.36	0.7	3.25	1.1	3.11	1	3	1.3

The data suggest that younger teachers tend to report higher levels of knowledge about the STEAM approach, while teachers aged 55 or older show the lowest knowledge levels. Interestingly, older teachers report applying the STEAM approach more frequently in the classroom than younger teachers. Regarding appraisal of the methodology, responses are moderately positive across all age groups, although the average evaluation decreases slightly with increasing age. However, the Kruskal–Wallis test results presented in Table 9 indicate that none of these differences are statistically significant.

Table 9. Kruskal–Wallis test statistics by age group

Item	Chi-square	df	*p*-value
Knowledge	4.1317	3	0.3885
Frequency	4.6315	3	0.3272
Appraisal	1.3218	3	0.8577

Fig. 2 provides a visual comparison between the mean values for each age group and the overall mean values obtained in the study. As illustrated in the figure, although minor variations can be observed among age groups—particularly in perceived knowledge and frequency of implementation—the overall pattern remains relatively consistent across the sample.

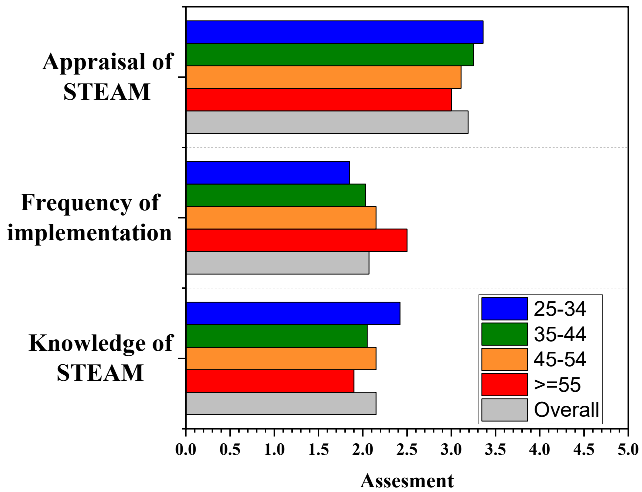

Fig. 2. Comparison of mean responses by age group and overall averages.

D. School Type

Table 10 presents the descriptive statistics when responses are differentiated according to the type of school where participants work.

Table 10. Means and standard deviations by school type

Item	Private	SD	Concerted	SD	Public	SD
Knowledge	2.38	0.74	2.50	1.17	2.01	1.03
Frequency	2.00	0.93	1.92	0.89	2.13	1.09
Appraisal	3.00	0.82	3.29	0.69	3.18	1.09

The descriptive results reveal slight differences across school types. Teachers working in private and state-funded private (concerted) schools report somewhat higher levels of knowledge of the STEAM approach compared with teachers in public schools. In contrast, teachers from public schools indicate a slightly higher frequency of STEAM implementation in their classrooms. Regarding the appraisal of the methodology, the highest average evaluation is reported by teachers working in state-funded private schools. However, the Kruskal–Wallis test results presented in Table 11 indicate that none of these observed differences are statistically significant.

Table 11. Kruskal–Wallis test statistics by school type

Item	Chi-square	df	*p*-value
Knowledge	4.3054	2	0.1162
Frequency	0.4747	2	0.7887
Appraisal	0.3065	2	0.8579

Fig. 3 provides a visual comparison between the mean values obtained for each school type and the overall mean values. As illustrated in the figure, although minor variations can be observed among the three types of schools, the overall pattern of responses remains relatively similar across the different educational contexts.

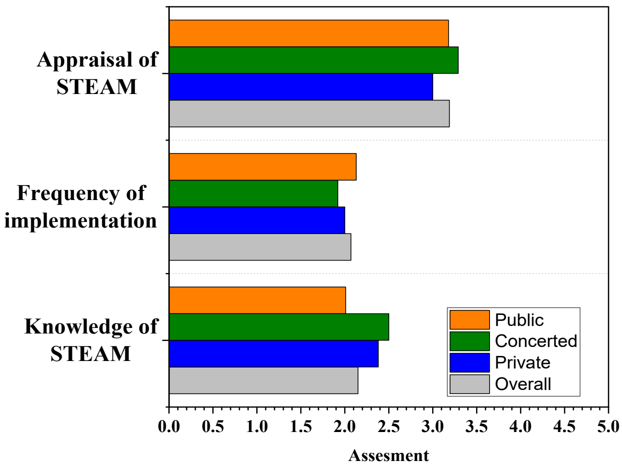

Fig. 3. Comparison of mean responses by school type and overall averages.

E. Teaching Methodology

Table 12 shows the results according to the teaching methodology most frequently used by participants.

The descriptive results indicate that teachers who combine lectures with active methodologies report the highest levels of knowledge of the STEAM approach and the highest frequency of classroom implementation. In contrast, teachers who rely primarily on lecture-based instruction tend to report lower levels of knowledge and less frequent use of the methodology. Regarding appraisal of the STEAM approach, teachers using active or mixed methodologies also report higher average evaluations compared with those relying mainly on traditional lectures.

Table 12. Mean values by teaching methodology

Item	Lecture	Lecture + dynamics	Lecture + active	Only active
Knowledge	1.93	1.78	2.47	2
Frequency	1.57	1.63	2.58	1.33
Appraisal	2.25	2.9	3.39	3.33

The Kruskal–Wallis test results, presented in Table 13, confirm that the differences observed across teaching methodologies are statistically significant for both knowledge of the STEAM approach and frequency of implementation. However, no statistically significant differences were found for the appraisal variable.

Fig. 4 illustrates the comparison between the mean values obtained for each teaching methodology and the overall averages of the study. As shown in the figure, teachers who combine lectures with active learning strategies clearly report higher levels of knowledge and more frequent use of the STEAM approach, while differences in the appraisal of the methodology are less pronounced across the different teaching strategies.

Table 13. Kruskal–Wallis test statistics by teaching methodology

Item	Chi-square	df	*p*-value
Knowledge	12.705	3	0.01281*
Frequency	28.953	3	0.000008*
Appraisal	6.9378	3	0.1392

Note: * indicates statistical significance at $p < 0.05$.

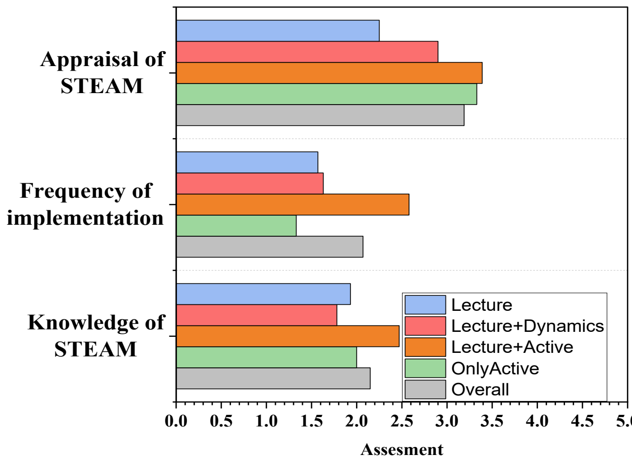

Fig. 4. Comparison of mean responses by teaching methodology and overall averages.

V. Discussion

A. STEAM Adoption: Knowledge, Implementation, and Educational Context

The results of this study provide information into teachers' knowledge, implementation, and perceptions of the STEAM approach in Spain. The results indicate that the level of knowledge about the STEAM methodology and the frequency of its implementation remain relatively low, although teachers who have applied it tend to evaluate the experience positively. These results suggest that STEAM is still in a progressive stage of adoption within educational practice, despite its increasing presence in educational discourse and policy.

One possible explanation for this situation lies in the broader transformation of educational systems driven by technological and social changes. The growing presence of digital technologies in education, particularly since the COVID-19 pandemic, has intensified the need to rethink teaching methodologies and integrate digital tools into learning environments [1]. However, as previous research has highlighted, the incorporation of technological resources alone does not guarantee meaningful learning outcomes. Instead, effective educational innovation requires the development of pedagogical frameworks capable of integrating technology, content knowledge, and appropriate teaching strategies [9, 27].

Within this context, the STEAM approach has emerged as a multidisciplinary educational framework that integrates scientific and technological knowledge with creativity and problem solving [14]. The theoretical foundations of STEM and STEAM education emphasize the importance of interdisciplinary learning experiences that connect scientific disciplines and promote the development of transversal competencies such as critical thinking, collaboration, and innovation [20, 21]. Nevertheless, the successful implementation of such approaches depends heavily on teachers' preparation and their ability to integrate these methodologies into their classroom practice [25].

B. Teacher Preparedness and Professional Development

The relatively low level of knowledge of the STEAM approach reported by participants in this study may therefore reflect the challenges associated with teacher training in innovative methodologies. Previous research has highlighted that many teachers feel insufficiently prepared to implement integrated STEM or STEAM approaches due to limited training opportunities and uncertainty about how to design interdisciplinary learning activities [38]. Similarly, studies on teacher professional development in STEAM education have shown that teachers' confidence and willingness to implement these approaches are closely linked to their previous training and experience [36, 37].

Despite the moderate levels of knowledge and implementation observed in this study, the generally positive appraisal of the STEAM methodology suggests that teachers recognize its potential educational value. This finding is consistent with previous research indicating that integrated STEM and STEAM approaches can support active learning, promote inquiry-based practices, and enhance students' engagement with scientific and technological subjects [18, 24]. In addition, the integration of artistic and creative components within STEAM has been identified as a key element for fostering innovative thinking and interdisciplinary problem solving [14].

Recent research has further highlighted that overcoming barriers to the integration of digital and interdisciplinary pedagogies requires structured and context-sensitive professional development programs, capable of addressing both technical and pedagogical challenges faced by teachers [30]. In this sense, the effectiveness of STEAM implementation is closely linked not only to training availability, but also to how such training responds to real classroom constraints.

C. Sociological and Pedagogical Factors Influencing STEAM Adoption

The results also reveal the existence of certain differences according to sociological and academic variables. Male teachers reported significantly higher levels of knowledge of the STEAM methodology than female teachers. Similar gender differences in teachers' perceptions and practices related to STEAM have been identified in previous studies, which suggest that attitudes toward technology and innovation may vary across demographic groups [35, 39]. However, it is important to interpret these results cautiously, as the differences observed in this study were limited to perceived knowledge and did not extend to the frequency of classroom implementation or the overall appraisal of the methodology.

From a more critical perspective, these differences should not be interpreted as evidence of substantial disparities in competence but may instead reflect variations in self-perception or confidence levels, as suggested in previous literature. Furthermore, these findings point to the importance of considering socio-cultural factors and professional identity when analyzing teachers' engagement with innovative pedagogies, as such factors may influence how teachers perceive and report their own competencies [31].

Age-related patterns were also observed in the data. Younger teachers reported higher levels of knowledge of the STEAM approach, whereas older teachers indicated slightly higher frequencies of classroom implementation. These findings may reflect differences in professional experience and exposure to new educational approaches. Previous research has shown that teachers who participate in professional development programs or have greater teaching experience often develop more positive attitudes toward integrated STEAM education and are more likely to apply it in their teaching practice [39–41].

Another relevant finding concerns the influence of teaching methodology on the knowledge and implementation of the STEAM approach. Teachers who combine traditional lectures with active learning strategies reported higher levels of knowledge and more frequent use of STEAM. This result is consistent with research highlighting the role of active methodologies, such as project-based learning and inquiry-based learning, in facilitating the integration of STEM and STEAM approaches in the classroom [17, 24]. These methodologies encourage interdisciplinary collaboration and allow students to engage with real-world problems, which are central characteristics of STEAM education [20].

In this regard, these findings can be interpreted through the TPACK framework, as teachers who integrate active methodologies may exhibit a more developed interaction between pedagogical and technological knowledge, facilitating the adoption of interdisciplinary approaches such as STEAM. This perspective aligns with recent conceptual developments that emphasize competency-based approaches within TPACK, highlighting the integration of computational thinking, design thinking, and pedagogical competencies as key drivers of effective STEM/STEAM implementation [33].

D. Implications for Educational Practice and Policy

The high proportion of teachers expressing interest in receiving training related to the STEAM approach is particularly noteworthy. More than ninety-five percent of participants indicated that they would like to receive training or would at least consider it. This finding reinforces the importance of strengthening teacher training programs focused on interdisciplinary and technology-enhanced pedagogies. Previous studies have emphasized that effective teacher training is a key factor for the successful implementation of STEM and STEAM initiatives in educational institutions [8, 28].

From a practical perspective, these results emphasize the need for targeted professional development programs that explicitly address the integration of content, pedagogy, and technology within interdisciplinary contexts. In addition, educational policies should promote institutional conditions that support methodological innovation, including time for collaborative planning, access to resources, and the implementation of active learning strategies.

Moreover, recent studies underline that teachers' experiences, narratives, and contextual challenges play a crucial role in shaping how innovative practices are adopted and sustained over time, reinforcing the need for flexible and context-aware training models [32].

At a policy level, this implies the need for systemic strategies that align curriculum design, teacher training, and institutional support structures, ensuring that STEAM is embedded as part of a coherent educational framework rather than as an isolated innovation.

Therefore, while the STEAM approach is gradually gaining recognition among teachers, its effective integration into classroom practice still requires further support, particularly in terms of teacher training and methodological guidance. Strengthening professional development opportunities and promoting interdisciplinary collaboration among teachers may therefore play a crucial role in facilitating the broader adoption of STEAM in educational contexts.

E. Limitations and Future Research

This study presents several limitations that should be explicitly acknowledged. First, the use of a non-probabilistic convenience sampling strategy may introduce self-selection bias, as participants were recruited through professional and academic networks. Consequently, teachers with a prior interest in innovation or STEAM methodologies may be overrepresented in the sample, which could lead to an overestimation of positive perceptions or engagement with this approach.

The limited number of items reflects a deliberate design choice aimed at ensuring a concise instrument and a high response rate. However, this may restrict the depth of the measurement, and future studies should employ more comprehensive multi-item scales.

Furthermore, the sample cannot be considered fully representative of the broader population of secondary school teachers in Spain, particularly with respect to regional distribution, institutional diversity, and varying levels of experience. As a result, the results should be interpreted with caution, especially in terms of generalizability beyond the specific sample analyzed in this study.

In addition, the relatively sample size may limit the statistical power of the analyses, particularly when comparing subgroups across sociological and academic variables. While non-parametric tests were used to mitigate distributional assumptions, smaller subgroup sizes may still reduce the sensitivity to detect meaningful differences.

Taken together, these limitations suggest that the results should be understood as indicative rather than conclusive. Future research should aim to employ probabilistic sampling strategies and larger, more diverse samples to enhance the external validity and robustness of the findings.

VI. Conclusion

This study provides empirical evidence about teachers' knowledge, implementation, and perceptions of the STEAM approach in Spain. The results indicate that, although the STEAM methodology is increasingly recognized in educational discourse, its practical implementation in classrooms remains limited. Teachers generally report moderate levels of knowledge and relatively low frequencies of application, suggesting that the integration of STEAM into everyday teaching practices is still in a developmental stage.

Despite this limited implementation, the generally positive appraisal reported by teachers indicates that the methodology is perceived as pedagogically valuable once it is applied. In particular, the results highlight that teachers who combine traditional instruction with active learning methodologies show higher levels of knowledge and greater use of the STEAM approach. This finding reinforces the idea that active and interdisciplinary teaching practices are closely linked to the successful adoption of STEAM methodologies.

Another relevant contribution of this study is the identification of differences associated with sociological variables such as gender and age, as well as academic variables such as teaching methodology. These findings suggest that the adoption of STEAM may be influenced not only by institutional factors but also by teachers' professional experience and pedagogical tactics.

Perhaps the most significant implication of the results is the strong interest expressed by teachers in receiving training related to the STEAM methodology. This highlights the importance of strengthening professional development programs aimed at supporting teachers in the design and implementation of interdisciplinary learning experiences.

Future research should further explore the factors that facilitate or hinder the integration of STEAM in educational contexts. Studies involving larger samples, qualitative methodologies, or classroom-based analyses could provide deeper insights into how STEAM practices are developed and how they impact teaching and learning processes.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Conceptualization, D.V.; Methodology, D.V., A.A.-S., and A.d.B.; Formal analysis, D.V, P.T., A.A.-S. and A.d.B.; Investigation, P.T. and M.S.J.; Data curation, P.T. and A.A.-S.; Writing—original draft preparation, D.V., A.A.-S., and A.d.B.; Writing—review and editing, D.V., A.A.-S., M.S.-J. and A.d.B.; Supervision, D.V. All authors have read and agreed to the published version of the manuscript.

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