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ATS-STEM: Global Teaching Methodology to Improve Competences of Secondary Education Students

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Abstract: Previous studies agree on the benefits of improving the relevant competences in students by applying globalized learning methodologies and projects in the STEM fields (Science, Technology, Engineering and Mathematics). However, few studies have focused on whether including other subjects in Humanities, Arts and Social Sciences (HASS) in these projects improves high school students' perceptions on improvement in these skills. The objective of this work was to study the effect of participation in interdisciplinary teaching projects (STEM and HASS), which promote globalized and project-based learning, on the perception of self-efficacy of secondary school students in basic competences for learning. It also analyzes the modulating role of gender on said perception. High school students from Galicia participated in this study. Both before and after participating in teaching projects according to the MODEL of the ATS-STEM project, they completed a questionnaire on self-efficacy in the eight key competences for STEM learning defined in the model: disciplinary STEM competences, problem solving, innovation and creativity, communication, critical thinking, metacognitive skills, collaboration and self-regulation. The results showed an improvement in all the competences evaluated (although only the men showed an increase in collaboration). Nevertheless, there was a lower perception of competence in women than in men in discipline competences, problem solving and metacognitive skills. Therefore, the benefits of interdisciplinary ATS-STEM learning experiences on the self-efficacy perceived by high school students were confirmed, although the results continue to show a gender gap.

Keywords: STEM; STEAM; HASS; gender; stereotypes; key competences for lifelong learning

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1. Introduction

The scientific field and the organizations responsible for educational and employment policies highlight the need to train new generations of secondary school students. It is especially vital for women due to the existing gender gap in the specific competences associated with the subjects of Science, Technology, Engineering and Mathematics (STEM). This need is supported by a variety of factors such as the demands of the working environment [1–3], in which the relationship between the promotion of jobs in the field of technology and economic development has been verified both in developed [4] and developing countries [1]. Likewise, the integration of Information and Communication Technologies (ICT) in all areas of personal and professional life requires specific training within formal education [5].

1.1. STEM Learning in Secondary School

Despite this socio-economic relevance, several studies found a worrying drop in the vocational interest of secondary school students in STEM subjects [6]. A number of aspects have been identified as contributing to this decline in interest. On the one hand, STEM subjects have dense syllabuses that are difficult to assimilate when they are taught in a generic way, using traditional methodologies to impart the basic foundations compared to more innovative methodologies from the didactic point of view [6,7]. On the other hand, studies have found a clear gender gap, with women underrepresented in university careers linked to STEM, which already manifests itself early on [5,8–11]. Notwithstanding, it has been shown that a high percentage of pre-university students considered men and women as equally good professionals in STEM jobs [12]. Among other factors, stereotypes about gender roles have been identified both in the family and at school. This influences their personal choices and proof of this is found in the fact that women choose areas not related to STEM due to concerns about their future family reconciliation [8]. This lack of interest is of special relevance considering that the niche of potential workers in the STEM field is greatly reduced [5,8,9].

Therefore, strategies have been put in place to promote interest in STEM subjects in secondary education. A widely implemented strategy has been to integrate the education of the different STEM contents in the same subject, sponsored by different educational policies [2]. However, this strategy is not without criticism [2]. In addition, the suitability of integrating content and strategies of subjects related to Art and Humanities has recently been pointed out, giving rise to the STEAM concept [13,14]. This integration contributes not only to reinforcing competences associated with these disciplines, but also to improving understanding and increasing interest in STEM content [14].

1.2. Project-Based Learning and STEM Learning

Nevertheless, the main revolution has been to link this strategy to didactic innovation procedures in STEM/STEAM disciplines, namely globalized learning and project-based learning (PBL). PBL is based on constructivist principles, learning through real, specific contexts and involving the students in their own learning [15]. These approaches pursue the involvement of students in solving real-life problems, which allows the application of interdisciplinary concepts and procedures and encourages the generalization of knowledge and motivation towards these disciplines [7]. Since these are the mechanisms for the construction of scientific knowledge, in some cases agents external to secondary education have been involved. Such is the case of the involvement of university institutions in the education of secondary school students through agreements and collaborations [16].

It has been demonstrated that the application of PBL to STEM/STEAM training has numerous advantages over classical teaching methodologies [7]. From a didactic point of view, the degree of understanding of the concepts beyond the realization of specific tests for each subject stands out. This allows students to connect and generalize the knowledge of the different disciplines [17], as well as to develop the capacity to apply said knowledge [18,19]. From a motivational point of view, an increase in curiosity towards the disciplines [20] as well as interest and participation in these activities [3,6,21] is of great relevance to promoting the vocational interest of students towards STEM professions. Furthermore, many studies report the benefits of PBL in reducing the gender gap as they increase women's interest in STEM disciplines [8,9,11].

The application of PBL to STEM content also brings the advantage of facilitating the acquisition of transversal competences for learning [22] which are of great relevance for all curricular disciplines. Nevertheless, for reasons previously mentioned as being associated with STEM disciplines (density of syllabuses, application of traditional methodologies), they are closely related to the success of these disciplines; therefore, we will consider them basic competences for STEM learning. In this sense, previous research has highlighted that these projects have facilitated the acquisition of problem-solving skills, understood as the ability to find solutions to specific problems or demands of tasks [23–26]. Studies have also revealed a hike in critical thinking [27,28], that is, the ability to analyze and synthesize information and make judgments based on evidence. Creativity, generating new ideas and applying them when facing the demands of the environment [14,29,30] have also seen an upsurge, in this case especially when integrated with art and humanities (thus, STEAM projects [14,31–33]). Other outstanding competences are communication and collaboration, largely fostered by the involvement of students in group work while participating in these projects [34]. Other competences favored by this methodology are self-regulation or autonomous learning [35,36], intrinsically linked to the curiosity to learn and managing time for learning [20]. Finally, other studies have indicated the advantage of PBL to improve metacognitive skills, which are those that allow reflection on one's own ideas and allow one to regulate learning [37,38].

Despite the abundant literature highlighting all the advantages of applying globalized approaches to teaching and PBL in STEM/STEAM content, few studies have focused on contrasting students' perceptions of how these methodologies help in the acquisition of STEM-specific competences, as well as other basic competences related to the development of activity in these areas of study and work. This lack of information is shocking, given that the main motivational component for the selection of a professional future is undoubtedly mediated by the students' own perception of their abilities [39].

Consequently, the objective of this study is to contrast whether the implementation of teaching projects based on the ATS-STEM model (interdisciplinary, globalized and problem-oriented) improves the skills of secondary school students, both specific and key to STEM learning. The specific objectives would consist of: (a) checking the level of self-perceived competence on key competences for STEM learning (disciplinary competences, problem solving, innovation and creativity, critical thinking, communication, collaboration, self-regulation of learning and metacognitive competences) in secondary school students; (b) studying the evolution of these competences in secondary school students following the implementation of teaching projects based on the ATS-STEAM model; and (c) studying the relevance of gender in secondary school students on the competences evaluated, both before and after their participation in teaching projects based on the ATS-STEM model.

Depending on the advantages put forward in previous literature, we expect to find an improvement in all or most of the competences assessed after the implementation of ATS-STEM projects. We further expect that female secondary school students will perceive a lower level of key competences for STEM learning than their male counterparts, although we expect to see less of a difference after participating in the projects.

2. Materials and Methods

2.1. Design and Participants

The ATS-STEM project started with the design of an ad hoc conceptual framework for STEM education, which is thoroughly explained in [22]. That framework defined and conceptualized 8 key competences for STEM learning. Thus, we performed an evaluative study using a mixed approach (qualitative and quantitative) with a complex architecture of informants, instruments and fieldwork. In this article, we focus on the results of the quantitative study carried out through a quasi-experimental design in students at secondary schools in Galicia (northwest Spain). Specifically, the schools were Compulsory Secondary Education centers covering 12 to 16 years of age and structured in two cycles: the first includes the first 3 years and the second the last year. The study was carried out during the academic years 2019–2020 and 2020–2021. The data of the participants were collected anonymously (with the help of the teachers involved in the ATS-STEAM projects implemented in the educational centers) in two phases, before and after the implementation of ATS-STEAM projects in their classrooms. Of the participating schools, 69% were "state schools" and the remaining 31% were "private state-funded schools".

In the initial phase, the total sample of the present study was composed of 868 students: 419 students were women, 404 were men, 9 declared themselves as non-binary and 24 preferred not to provide information about their gender. In the final phase, 794 students participated, of whom 381 were women, 364 were men, 21 were non-binary and 28 preferred not to provide information about their gender. Given the small number of participants with non-binary gender, data from these participants were not used in the statistical analyses, nor were data from those who did not report their gender. Figure 1 shows the distribution of men and women in the sample analyzed for the initial and final phases (N = 835 and

N = 745, respectively). Depending on the course, the students were distributed both at the start and at the end as follows: 26.2% from the 1st year, 6% from the 2nd year, 36.1% from the 3rd year and 31.5% from the 4th year, and at the end.

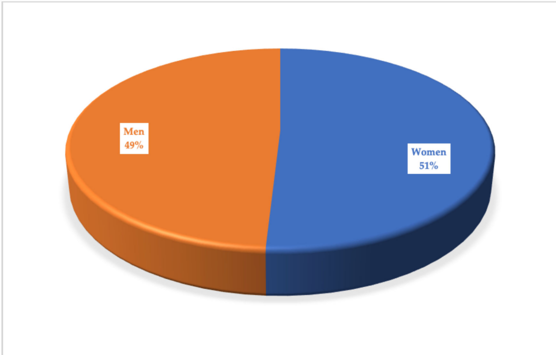

Figure 1. Distribution of the sample of students according to gender before and after participation in ATS-STEAM projects.

2.2. Instrument

For the evaluation of the competences in this study, an ad hoc questionnaire was designed (see Figure 2) to obtain direct information of the basic competences in STEM learning that might not be assessed with more general self-efficacy questionnaires. In it, 8 items were presented (one per evaluated competence) in which a description of each competence was provided with examples so that the participants could self-assess their level of acquisition of these competences. To do this, participants had to score their level of competence on a 5-point Likert scale (Very poor, Not good, All right, Good and Excellent). It was created using the Forms application, included in the Microsoft Office 365 package (Redmond, WA, USA).

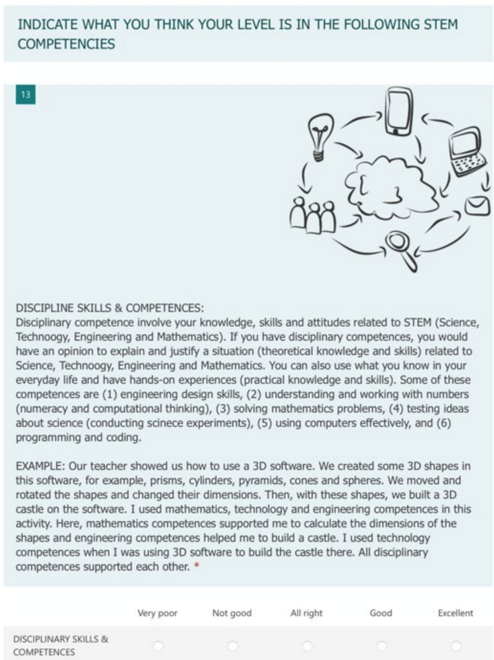

Figure 2. Example of one of the competences assessed through the ATS-STEM questionnaire.

2.3. ATS-STEM Interdisciplinary Teaching Projects

This study is part of a broader project, specifically the competitive European project KA3 "Assessment of Transversal Skills in STEM (ATS-STEM)". It is being carried out in 8 countries and includes a network of partners from 12 educational institutions. The objective of this project is to provide teachers and students with the necessary and effective formative digital assessment approaches for the development of key competences for STEM learning. This model has been developed, applied and evaluated through a pilot test in the classrooms of schools in 7 European countries.

The projects were designed following the principles of the ATS-STEM model developed (Problem Solving Design and Approaches, Disciplinary and Interdisciplinary Knowledge, Engineering Design and Practices, Appropriate Use and Application of Technology, Real-world Contexts and Appropriate Pedagogical Practices) [22]. In this way, the different learning cycles of the teaching projects that were related in all cases to a United Nations Sustainable Development Goal (SDG) were designed. These projects were launched with an interdisciplinary approach and involved all kinds of curriculum subjects from STEM and HASS (Humanities, Arts and Social Sciences).

All students participated in the learning cycles implemented in the centers within the framework of the ATS-STEM project. Different materials, examples and tools to help the design of ATS-STEM teaching projects were developed so the participating teachers from all European countries could work according to the same pedagogical model based on 6 pedagogical principles [22]:

1. Problem Solving Design and Approaches;
2. Disciplinary and Interdisciplinary Knowledge;
3. Engineering Design and Practices;
4. Appropriate Use and Application of Technology;
5. Real-world Contexts;
6. Appropriate Pedagogical Practices.

Training sessions were also held for the participating teachers and mentors who acted as advisors to the teaching staff for the adaptation of the ATS-STEM model to the customs and practices of each territory and each school. All teaching projects were carried out in a progressive sequence of 5 steps (Figure 3).

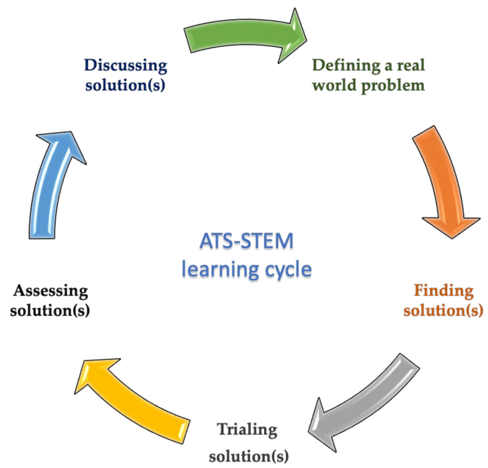

Figure 3. Steps of the ATS-STEM learning cycle.

In the first phase (defining a real-world problem), the teachers involved introduced the Sustainable Development Goals of the United Nations and all those involved defined the most relevant problems to be addressed and their relationship with the SDGs. In this way, the learning objectives were shared. In the second phase (finding solutions), the teaching staff guided the students in understanding the problems raised and their effects in their real and immediate context and in the search for and definition of solutions. During the third phase (trialing solutions), the students designed, developed and tested the previously defined solutions to the problem and the teaching staff guided them in the experimentation. Throughout the fourth phase (assessing solutions implementation), the teaching staff guided the students in the evaluation of the effectiveness of the solutions designed and tested by them. In the fifth and final phase (discussion), the students, guided by the teaching staff, carried out a discussion and group analysis of the entire process and the results obtained.

The methodology was active and participatory, and the autonomous work of the students and the collaborative work with multiple strategies and types of groupings under the supervision of the teacher(s) were enhanced. As a result, but as part of a formative evaluation, the students created different artifacts or productions generally using a digital medium and relying on digital tools of communication, collaboration and dissemination of content. This is especially relevant in the framework of PBL, in comparison to other collaborative pedagogical approaches, which requires concluding with an end product [15].

During the implementation of the STEM projects, the 8 key competences for STEM learning defined in the model and considered instrumental for the execution of the teaching projects were worked on. Said competences were directly linked to the "key competences for lifelong learning" of the European framework of reference: learning to learn, communication in mother tongue and in foreign languages, mathematical competence and basic competences in science and technology, initiative and entrepreneurship [40].

2.4. Data Analysis

To represent the results, descriptive statistics were obtained (means, standard deviations, frequency in percentage of each type of response) for each item of the questionnaire used, both before and after the participation of the students in the ATS-STEAM projects.

Furthermore, to contrast the effect of phase (initial vs. final) and gender on secondary school students' perceptions of their competences, and since the data do not follow a normal distribution, a robust ANOVA with two factors (Phase $\times$ Gender) was performed using trimmed means [41]. The advantage of these contrasts with respect to classical non-parametric tests is that they allow us to contrast if there is a significant effect of the interaction between factors. No degrees of freedom are provided since an adjusted critical value is used [41].

In all cases, the significance threshold (α) was set at 0.05. In case of significant effects of the interaction between factors, multiple comparisons were made by pairs a posteriori (Mann–Whitney U) adjusting the level of significance by Bonferroni correction. Descriptive statistics were obtained using the SPSS v.25.0 statistical package for Mac (IBM Inc., Armonk, NY, USA), while statistical contrasts were performed using the R statistical package [42], using the foreign [43], base [42] and WRS2 libraries [41].

3. Results

3.1. Descriptive Statistics

The results of the initial questionnaire showed that secondary school students mostly perceived their level of competence at intermediate levels (see Table 1), with the most selected option being "All right" for all competences except communication and collaboration, in which the most selected option was "Good".

Table 1. Initial self-assessment of key competences for STEM learning by students participating in the ATS-STEAM project.

	Very Poor	Not Good	All Right	Good	Excellent
Disciplinary STEM competences	4.67%	29.46%	37.37%	20.72%	7.78%
Problem-solving	1.32%	21.32%	43.35%	27.07%	6.95%
Innovation and creativity	2.99%	22.04%	39.64%	26.35%	8.98%
Communication	1.80%	16.53%	31.86%	34.61%	15.21%
Critical thinking	2.16%	22.63%	39.64%	26.59%	8.98%
Metacognitive skills	1.68%	23.35%	39.16%	24.07%	11.74%
Collaboration	1.92%	13.41%	32.22%	33.65%	18.80%
Self-regulation	7.54%	25.03%	35.33%	23.23%	8.86%

In line with this distribution, the mean scores (see Table 2) in each competence were around 3, with a range between 2.97 (disciplinary STEM competences) and 3.54 (collaboration).

Table 2. Means and SDs obtained in the key competences for STEM learning of students at the start and after participation in ATS-STEAM projects.

	Initial		Final	
	Mean	**SD**	**Mean**	**SD**
Disciplinary STEM competences	2.97	1.00	3.25	1.02
Problem-solving	3.17	0.89	3.45	0.87
Innovation and creativity	3.15	0.96	3.40	0.97
Communication	3.45	1.00	3.61	1.01
Critical thinking	3.18	0.95	3.48	0.94
Metacognitive skills	3.21	0.98	3.46	0.95
Collaboration	3.54	1.01	3.62	0.96
Self-regulation	3.00	1.07	3.22	1.02

In the case of the final questionnaire, this same distribution is maintained (see Table 3) with higher response frequencies at the intermediate level for all competences except communication and collaboration. However, a higher frequency of responses can be seen in the intermediate and high options than in the case of the final questionnaire, which is reflected in the means (see Table 2), in which the self-perceived level of skills acquisition ranged from 3.22 (self-regulation) to 3.62 (collaboration).

Table 3. Final self-assessment of key competences for STEM learning by students participating in the ATS-STEAM project.

	Very Poor	Not Good	All Right	Good	Excellent
Disciplinary STEM competences	4.43%	17.32%	38.68%	28.05%	11.54%
Problem-solving	1.48%	10.74%	40.00%	37.32%	10.47%
Innovation and creativity	2.01%	16.24%	34.63%	34.09%	13.02%
Communication	1.74%	12.21%	30.74%	34.23%	21.07%
Critical thinking	0.94%	13.56%	37.72%	32.62%	15.17%
Metacognitive skills	1.61%	12.35%	40.40%	30.07%	15.57%
Collaboration	1.61%	10.74%	30.34%	38.93%	18.39%
Self-regulation	4.16%	19.46%	38.12%	26.58%	11.68%

3.2. Statistical Contrasts

Figure 4 shows the level of competences perceived by secondary school students in the initial phase and in the final phase, while Figure 5 compares the level of competences by gender.

The robust ANOVA (Phase × Gender) showed, for the item referring to specific STEM competences, a significant effect of the Phase factor (F = 38.33, $p \leq 0.001$), and the Gender factor (F = 33.89, $p \leq 0.001$), but no significant effect of the interaction was found (F = 0.12, $p = 0.725$). High school students reported having a higher level of disciplinary STEM competences after participation in ATS-STEM projects (mean = 3.25; DT = 1.02) in comparison to the phase prior to participation (mean = 2.97; DT = 1.00).

In addition, men reported having more disciplinary STEM competences (mean = 3.26; SD = 1.03) than women (mean = 2.94; DT = 0.98).

The robust ANOVA (Phase × Gender) showed, for the problem-solving competence, a significant effect of the Phase factor (F = 34.44, $p \leq 0.001$) and the Gender factor (F = 3.86, $p = 0.050$), but no significant effect of the interaction was found (F = 0.46, $p = 0.500$). High school students showed a higher level of problem-solving in the final phase (mean = 3.45; SD = 0.87) in comparison to the initial phase (mean = 3.17; DT = 0.89). Moreover, men reported having more disciplinary STEM competences (mean = 3.37; SD = 0.91) than women (mean = 3.23; DT = 0.86).

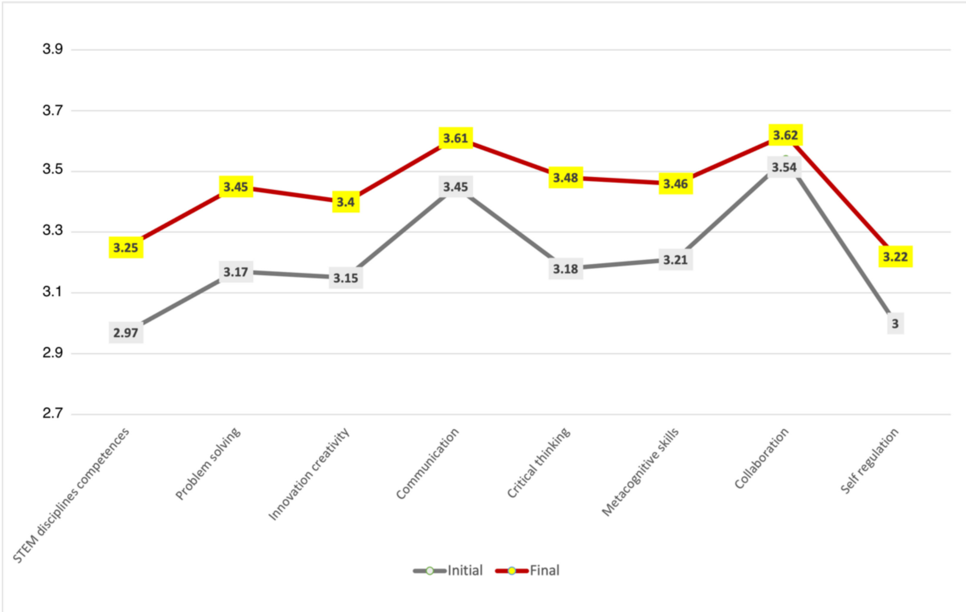

Figure 4. Students' level of competences at the start and after their participation in the ATS-STEM projects.

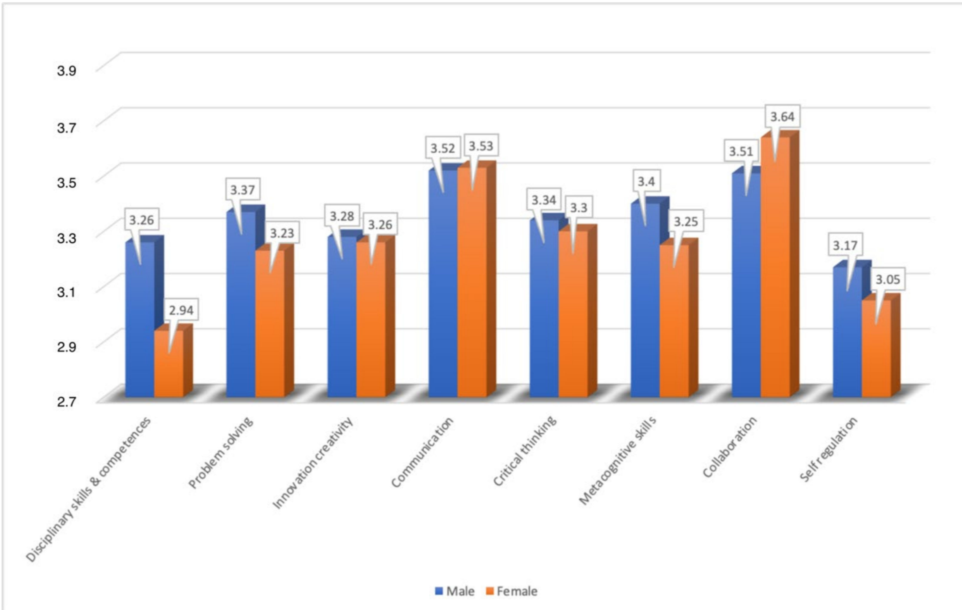

Figure 5. Level of competences at the start and after participation according to student gender.

The robust ANOVA (Phase × Gender) showed, for the innovation and creativity competence, a significant effect of the Phase factor (F = 29.01, $p \leq 0.001$), but no significant effect of the Gender factor (F = 0.44, $p = 0.508$), nor of the interaction between factors (F = 1.14, $p = 0.286$). High school students indicated that they had a higher level of this competence in the final phase (average = 3.40; SD = 0.97) in comparison to the initial phase (mean = 3.15; DT = 0.96).

The robust ANOVA (Phase × Gender) showed, for the communication competence, a significant effect of the Phase factor (F = 4.12, $p = 0.043$), but no significant effect of the Gender factor (F = 0.00, $p = 0.997$), nor was interaction between factors (F = 0.37, $p = 0.543$) found. High school students indicated a higher level of communication in the final phase (Average = 3.61; SD = 1.01) in comparison to the initial phase (mean = 3.45; DT = 1.00).

The robust ANOVA (Phase × Gender) showed, for the critical thinking competence, a significant effect of the Phase factor (F = 27.53, $p \leq 0.001$), but no significant effect of the Gender factor (F = 0.00, $p = 0.967$), nor was interaction between factors (F = 2.05, $p = 0.153$) found. High school students indicated that they had a higher level of this competence in the final phase (average = 3.48; SD = 0.94) in comparison to the initial phase (mean = 3.18; DT = 0.95).

The robust ANOVA (Phase × Gender) showed, for metacognitive skills, a significant effect of the Phase factor (F = 21. 69, $p \leq 0.001$), and the Gender factor (F = 7.97, $p = 0.005$), but no significant effect of the interaction was found (F = 0.24, $p = 0.621$). High school students reported having a higher level of metacognitive skills in the final phase (mean = 3.46; DT = 0.95) with respect to the initial phase (mean = 3.21; DT = 0.98). In addition, men reported having more metacognitive skills (mean = 3.40; SD = 0.98) than women (mean = 3.25; DT = 0.96).

The robust ANOVA (Phase × Gender) showed, for the collaboration competence, a significant effect of the Gender factor (F = 5.46, $p = 0.020$), and of the interaction between Phase and Gender (F = 6.07, $p = 0.014$), but no significant effect of the Phase factor (F = 1.22, $p = 0.270$) was found. Women reported having a higher level of competence in collaboration (mean = 3.64; SD = 0.99) than men (mean = 3.51; DT = 0.97), although this effect was modulated by the Phase factor, since multiple pairwise comparisons showed that the significant effect of Gender took place in the initial phase (U = 74,434.00, $p = 0.002$), but not in the final (U = 68,586.50, $p = 0.787$). In fact, multiple pairwise comparisons showed that there was an effect of the Phase factor in the case of men (U = 71,639.00, $p = 0.009$) but not in that of women (U = 72,544.50, $p = 0.738$).

Finally, the robust ANOVA (Phase × Gender) showed, for the self-regulation competence, a significant effect of the Phase factor (F = 14.73, $p \leq 0.001$), but no significant effect of the Gender factor (F = 2.77, $p = 0.097$), nor was interaction between factors found (F = 0.47, $p = 0.496$). High school students indicated that they had a higher level of this competence in the final phase (average = 3.22; DT = 1.02) in comparison to the initial phase (mean = 3.00; DT = 1.07).

4. Discussion

The main objective of this study was to verify the effect of participation in teaching projects based on the ATS-STEM model on the perception of self-efficacy of secondary school students in key competences for STEM learning, as well as the modulating role of gender on said perception. The results reflected that the application of PBL methodologies improved the self-perception of the acquisition of key competences for STEM learning, although there was still a gender gap.

The results show that, in line with our hypotheses, the use of innovative ATS-STEAM teaching strategies leads to an improvement in self-perception about the level of acquisition of key competences for STEM learning in secondary school students. Classical theories directly relate perceived self-efficacy to performance in tasks [44], and in a very relevant way, to the creation of personal objectives [35]. Thus, the perception of one's own ability in STEM disciplines directly affects the academic performance of secondary school students in these subjects [35,44]. Moreover, this perception of their own abilities has been closely related to the choice of academic and professional careers [39], so this result is of great relevance given the interest on behalf of educational and labor policies of different countries to increase vocational interest in professions linked to sciences and technologies [1,4].

Improvements were observed in the key competences for STEM learning, problem solving and critical thinking, which are competences of great relevance for educational success in all disciplines of the curriculum. The increase in these skills is expected given that all the projects launched in this study were designed with a constructivist and practical approach and putting into practice interdisciplinary activities aimed at problem solving and strategies of continuous and formative evaluation. As for problem solving, this constitutes an essential competence of the curriculum of secondary school students [24], and constitutes an essential skill for the development of a scientific perspective of academic and work activity [24,26]. It is reasonable that this was one of the most favored competences in this study, given that in the ATS-STEM methodology adopted, the approach to real-life problems of applying a globalized and interdisciplinary approach to obtain solutions, guided experimentation and analysis of the process and its results clearly constitute the central elements of the teaching process [7]. Critical thinking, that is, being able to distinguish between relevant and irrelevant information and understanding which information is valid and which is speculative in order to reach appropriate conclusions [28], is equally considered a competence of high relevance for academic and professional performance in all disciplines of the curriculum [7].

Noteworthy and significant increases were also observed in the other competences assessed (except for one, collaboration, as we will discuss later). Therefore, consistent with the previous literature [7], project-based learning allowed for improvement of the self-perception of the level of acquisition of key competences for STEM learning, such as innovation and creativity, metacognitive skills and self-regulation. Previous studies have shown that project-based learning improves competences related to innovation and creativity, especially when integrating not only STEM subjects but also providing the perspective of the humanities [14,29–33], as in this study. Applying the concepts of different subjects and perspectives to solve the problems proposed in the projects, as well as collaborative work between peers, contributed to the improvement in the students' perception about their metacognitive skills, in line with previous studies [37]. Hence, it seems that participation in ATS-STEAM projects has encouraged secondary school students to perform deep and careful processing of their own knowledge and thoughts [45]. Finally, an increase in the perception of self-regulation was also observed. Leon et al. [46], using structural equation models, suggested that the processes of self-regulation of learning requires increasing the efforts or commitment of students to perform a specific task and the assimilation of concepts; strictly speaking, these are two highlights of the use of project-based learning methodologies [7].

The only competence in which a significant effect was not obtained between the pre-test and the post-test was collaboration. However, participation in ATS-STEAM projects modulated this competence, as reflected in the interaction between the phase and the gender of the students. Thus, although women showed a greater capacity for collaboration than men prior to participation in the projects, these differences disappeared after participation. It was then possible to verify that the participation of the students in the interdisciplinary projects led to an increase in the collaboration of the male secondary students. The absence of effect in the case of women could be motivated by high school students' already high perception of this competence prior to the completion of the study, which may have led to a ceiling effect.

Despite the aforementioned positive aspects, the results found, once again, less positive aspects, such as the continued existence of a certain gender gap in key competences for STEM learning. Thus, female secondary school students valued, to a lesser extent than male students, three of the competences evaluated, highlighting among them the disciplinary STEM competences along with problem solving and metacognitive skills. The gender gap in STEM fields has raised concern in the scientific community [8–11], where different factors have been identified as generating this inequality [8,10]. In this case, however, contrary to the initial hypotheses, the use of project-based learning methodologies did not make it possible to reduce the differences between boys and girls in secondary schools, even though this strategy has been suggested to favor women's vocational interest in STEM careers and professions [8,9]. There are two possible interpretations for this result. From a more encouraging point of view, given that the experiences implemented in the present study have made it possible to improve both genders (except for collaboration, in which only men have improved), it is possible that this improvement also allows a greater vocational orientation of secondary school students towards careers and professions related to STEM. Nevertheless, to contrast this possibility would require longitudinal studies to assess the evolution of the students who participate in these learning experiences over a prolonged period. Another interpretation is that the experiences designed were not inspiring enough to mobilize girls in secondary schools more, and perhaps experiences that introduce the gender perspective explicitly [47] or carry out the earliest experiences (primary education) would be required to avoid consolidating stereotypes of gender roles [8].

5. Conclusions

In conclusion, the application of global approaches and learning methodologies based on projects of the ATS-STEM model boosted self-perception and the acquisition of key competences for STEM learning. This is a fundamental aspect to consider in educational programs and policies focused on increasing the number of students, especially women, heading towards STEM careers and professions. Future studies should nonetheless focus on reducing differences in the perception of self-efficacy in key competences for STEM learning between boys and girls. This can be achieved through more specific programs that explain the gender perspective or by introducing learning experiences based on interdisciplinary projects from earlier stages of formal education. In addition, in order to always safeguard the anonymity of the participants, it was not possible to control the participants who carried out the initial and final questionnaires. Therefore, it was not possible to perform more specific analyses of repeated measures. Furthermore, although all participating schools had specific guidelines on how to implement ATS-STEM teaching projects, the theme of the specific projects, as well as the teachers in charge of implementing them, were different in each center, so a source of heterogeneity was added that could have affected the results. Future studies could try to implement the same projects with the same application guidelines to favor greater homogeneity in multicenter studies.

Nevertheless, it should be noted that the results of this study provide empirical support to affirm that interdisciplinary teaching using project-based learning strategies promotes competence-based learning in line with the recommendations of the European Commission on the key competences for lifelong learning [48].

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