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CHALLENGES AND OPPORTUNITIES TO TEACHING INQUIRY APPROACHES BY STE(A)M PROJECTS IN THE PRIMARY EDUCATION CLASSROOM

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Abstract. *This study analyses the teachers' perceptions of their capacity for designing and developing STE(A)M projects in a professional development programme (PD) conducted through a collaborative educational research project carried out between the University and the centres by the IndagaSTEAM Escuela project. Incorporating STEAM education in the classroom poses various challenges to teachers, among other aspects, associated with conceptualising, designing and applying the curricular integration of STE(A)M subjects, requiring training programs updates for this purpose. Hence, the design developed promotes applying an inquiry-based approach and adapting the integrative STE(A)M curriculum in the Primary Education classroom. Challenges and opportunities of the teachers' involvement have been analysed as a case study undertaken longitudinally between 2019 and 2022. Data have been compiled from a varied typology (rubrics evaluation, ad hoc interviews and questionnaires, using the Likert scale), which give an account of the global perception these educators have, on the one hand, of STE(A)M education and the inquiry approach and, on the other hand, of the collaborative learning scenario from the framework used.*

Keywords: *active learning, primary school teacher, teaching fundamental sciences, teacher skills*

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Introduction

Research Problem

The current education system in Spain (Organic Law, 2020) contemplates European recommendations on key skills for lifelong learning as a response to the demand for active learning in the training of responsible citizens. Its incorporation into the curriculum is therefore essential, being necessary to emphasise those aspects of learning orientated towards applying the acquired knowledge in response to new educational needs from an integrated approach.

In the case of science education, these needs are related to the promotion of the scientific-technological literacy of citizens and the development of scientific knowledge, skills and attitudes in different contexts, responding to everyday life situations that arise (Gilbert et al., 2011). It is an approach in which 21st-century learning scenarios require a treatment of science teaching that is able to link central disciplinary ideas with scientific and engineering practices, transversal concepts and all types of processes (Morrell et al., 2020).

This educational framework requires competent professionals, demanding that teachers have appropriate training in order for them to act in accordance with the same model they want to teach (Lupión-Cobos et al., 2023; Lupión-Cobos & Gallego-García, 2017). Thus, and with regards to teachers, new challenges are associated with the skills model that is added to the personal needs of teachers themselves, who, as reflexive professionals, must question ways of understanding how to teach science (Confederación de Sociedades Científicas de España [COSCE], 2011; European Commission, 2015; National Research Council [NRC], 2012).

Within this framework STE(A)M education arises, with benefits associated with the integration of the knowledge and promotion of scientific-techno-

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logical identities (Grimalt et al., 2021), technological-scientific literacy, social justice and sustainable development (Domènech, 2018) through the combining of technology and engineering via problems that are socially relevant for students (Ortiz-Revilla et al., 2020). STE(A)M in the Spanish educational context today promises innovation and preparation for the future. The term is becoming familiar not just to teachers and educators but also students and their families through a range of programmes, initiatives, and resources developed both inside and outside school (Castro-Rodríguez & Montoro, 2021; Couso & Simarro, 2020).

Its curricular inclusion in the Spanish education system has been developed thanks to the contribution, on the one hand, of the International Education Agency (UNESCO, 2019), which underlines the value of STE(A)M education for achieving the skills-based development the 21st-century demands and, on the other, of the Spanish Strategy for Science, Technology and Innovation 2021-2027 (Ministerio de Ciencia e Innovación [MICINN], 2021), which proposes tackling STE(A)M education from early stages, with the aim of reaching quality science through inclusion and diversity.

Although increasingly diverse studies are beginning to show guidelines and offer opportunities for the implementation of STE(A)M education in the Early Childhood, Primary and Secondary Education stages (Aguilera, 2022) under the umbrella of the current education law (Jefatura del Estado, 2020), the correct implementation of it is, however, both ambitious and complex, leading to teaching difficulties or tensions related to its conceptualisation or the training teachers themselves have (Toma y García-Carmona, 2021). These teaching tensions (Domènech, 2018; Pérez-Torres et al., 2021), which ultimately suppose a challenge to the transfer of STE(A)M education to science classrooms, are widely described in the recent literature related mainly to issues of curriculum organization and teacher training (Affouneh et al., 2020, El Nagdi et al., 2018; Margot & Kettler, 2019) as well as to personal characteristics and systemic factors, internal and external of institutions, being necessary to identify and evaluate them in favour of developing effective proposals.

In this regard, Professional Development (PD) programs focus on developing attitudes, skills and knowledge that are needed to provide useful training approaches to address the necessary teaching domains, which involve the selection and combination of curricular elements, teaching approaches, and the integration of contents and processes that participate in the learning STE(A)M situation.

Combining knowledge of what is already known about education in Science, Engineering or Mathematics with the addition of the potential and limits of disciplinary integration that STE(A)M multidisciplinarity entails and comfort with using technology in creative ways to increase integration of STE(A)M in classrooms (Gamse et al., 2017) requires a significant professional effort. Specifically, closely related to design, a high-level professional competence for teachers (De Vries, 2020). Hence, the treatment of STE(A)M education challenges requires support for progressive teacher professional development when implementing its principles in the classroom (De Meester et al., 2021).

On the other hand, the systemic nature of STE(A)M education implies different levels of internal teacher collaboration within school teams, all of them mobilizers of teacher exchanges, such as the availability of training material, jointly analyzing well-designed examples of STE(A)M curricular activities and providing the time to built the processes by the student-centred approach, letting students be active learners (Gasiewski et al., 2012).

PD is the key to helping teachers through the transformation process (Shahali et al., 2015). For this reason, it is essential to select, adapt and sequence proposals for it. Even more when linking them to the "decision-maker" and "teacher as designer" models. (De Vries, 2020).

Research Aim and Research Questions

Different studies have shown the importance of professional development programs in STE(A)M teacher training, both with practising teachers (Yildirim et al., 2022) and with teachers in initial training (Sahali et al., 2015).

The possible benefits of an integrated approach depend largely on how it is carried out, recognising teachers as a catalyst for the process (Margot & Kettler, 2019) and is limited by the specific and methodological training used. Related to the methodological aspects, Thibaut et al. (2018) concluded that collaborative work, interdisciplinarity, inquiry-based learning, problem- solving and design-based learning were the most used methodologies. The positive effect of inquiry-based teaching on student cognitive and attitudinal outcomes (Marshall & Alston, 2014), who extend their dedication to a regular interest in science, provide us with a valuable and promising tool to approach STE(A)M relationships in everyday school life, including problem-based, inquiry-based approaches, and design-based pedagogies or the assessment of multiple STE(A)M learning outcomes, among others in a series of defining characteristics associated with the design and implementation of STE(A)M units (Toma & Greca, 2018).

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However, it is surprising the small number of studies which analyse the enactment of integrated STE(A)M projects (McLure et al., 2022), particularly when teachers have indicated that they need more direction and support on how to effectively integrate learning areas (Margot & Kettler, 2019). In addition, Roehrig et al. (2021) have identified that making explicit connections between the content of the targeted disciplines is one of the essential factors for effective STE(A)M projects.

To put integrated STE(A)M projects into practice (McLure et al., 2022; Van Driel et al., 2012) implies teachers need design skills to elaborate classroom activities based on inquiry for STE(A)M education (Affouneh et al., 2020), combining conceptual learning with professional practices (McLure et al., 2022: Roehrig et al., 2021), taking into account the attitudes, beliefs, knowledge and teaching skills and also considering the existence of internal conditioning factors, along with interactions between these, their social environment and the education system itself (Affouneh et al., 2020; Lupión-Cobos et al., 2022).

The present study has focused on the Spanish context and aims to answer the following research questions:

- What level of teaching inquiry do Primary Education teachers show when implementing inquiry-based STE(A)M projects, and how do they evolve with practice?
- What is their perception, both at the level of implementation and of the established collaborative framework, as regards the advantages and difficulties encountered?

Research Methodology

Study Context & Design

The IndagaSTEAM Escuela project (Lupión-Cobos et al., 2023) has arisen to contribute to the need to promote the transfer of the results of science education research to educational institutions with the purpose of moving Science and Technology closer to schools and developing critical thought amongst their students (Millar & Osborne, 2009; Perines, 2018). The project is thus constructed as a useful training scenario for applying the objectives of STE(A)M education, combining the strategies of inquiry and contextualisation to do so as an integrative way to incorporate basic knowledge from several disciplines through active students´ participation and a mentoring of the training progression with design and implementation of own projects (Morrell et al., 2020).

The IndagaSTEAM Escuela project is an initiative promoted by public institutions made by the regional education administration of Andalusia via cooperation between colleges and universities (Lupión-Cobos et al., 2023). The project functions through interventions in which schools voluntarily participate in innovation and research processes orientated towards demands in improvements that involve their educational communities. The project has been developed for three years from a vision of STE(A)M education as a framework for linking knowledge and understanding via the interrelated threads of the specific content of the areas involved (Science, Technology, Engineering, Mathematics, Arts).

Employing situations relevant to students through the use of inquiry-based learning and the use of relevant contexts and socio-scientific issues as learning scenarios encourages students' interest and involvement and favours the understanding of the nature of science (Lupión-Cobos et al., 2022). The projects boost their capacity for making informed decisions, develop evidence-based arguments in relation to local, national and global problems, and put their key skills into practice by working cooperatively. The teaching staff involved in the scientific education research carry out the role of project trainers, orientating a training modernisation and guidance project for school teachers in the process of professional development for them that implies both theoretical foundation and ideas for practical implementation.

Thus, this research considers the beliefs of teachers about STE(A)M Education and the need for specific training for its implementation (Herro & Quigley, 2017) when contemplating the training objectives of the IndagaSTEAM Escuela project, which also articulated an expectation of professional practice for the transfer of innovative teaching approaches through the following aspects:

- Developing capacity for teaching inquiry, favouring its reflection processes and ability to manage transformative learning environments.
- Promoting a correct integration of the different elements that have an impact on the development of these innovative teaching approaches (curriculum, school organization, professional development and didactic material, among others).

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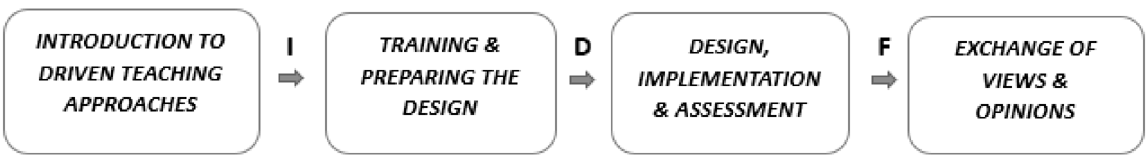
- Generating teaching-learning situations appropriate for conceptualising the contextualized teaching model, inquiry and STE(A)M undertaken, clarifying educational purposes and relationships in their treatment.
- Supporting teaching staff in their teaching capacity for selecting and designing projects that permit the formation of coherent and solid proposals with the intention of the proposed model, their identification and design. Thus, the design can be considered a form of complex problem-solving involving interdisciplinary thinking, handling multiple decisions and unanticipated problems, inquiry, collaboration in multidisciplinary teams, and a scientific basis from which to start (de Vries, 2020; De Meester et al., 2021).
- Systematically assessing the impact of actions and providing evidence/research evidence to guide improvement.

The counselling offered by the PD programme provided training support to promote an interrelated understanding of the processes involved, following a training progression plan (Figure 1), in three phases: Initial (I), Development (D) and Final (F)

Figure 1
Phases of the Training Programme



The training complexity involved in dealing with real-world problems and the very nature of the STE(A)M treatment (Couso & Simarro, 2020) to design projects was addressed using different levels of curricular integration (Pérez-Torres et al., 2021) and the participation of scientific inquiry processes in the activities to reflect conclusions or improve products. Thus, its educational components (context, problem and final product) were established to promote student competencies (Domenech-Casal, 2018) and the strategies for its teaching design and implementation.

The epistemological, scientific and educational scenario, which involved its planning and elaboration by the teacher and its established relationships, represents a starting line for research on teacher training in STE(A)M education.

The project was developed from 2019 to 2022 in a public Early Childhood and Primary Education Centre (CEIP) in Andalusia, in the framework of the collaborative education convention subscribed to between the Department of Education and Sport of the Regional Government of Andalusia (CEJA, 2017) and the public universities of Andalusia, in the sphere of educational innovation and research. A total of eight Primary Education teachers participated in a voluntary professional development initiative in order to tackle the challenge of introducing STE(A)M education as an approach for the improvement of the scientific-technological learning of their students.

At the heart of the IndagaSTEAM Escuela project, the teaching proposals designed by the researchers from the University of Málaga adhered to a model for the transfer between training and teaching practice, orientating themselves towards conceptualising and sharing with teachers their vision of the STE(A)M approach, clarifying both the educational proposals and goals (scientific-technological literacy of students, integration of the gender perspective, emerging technologies) of the teachers and selected perspectives and methodologies, with a strong basis on what it is already known about education in Sciences, Engineering and Mathematics, with the addition of the potential and limits of disciplinary integration in curricular treatments. Furthermore, there are internal and external systemic factors, associated with the need for collaborative scenarios in the centre for their putting into practice. To address this epistemological and behavioural structure, there was a contemplation of frameworks throughout the three academic years of the development of the project, with teaching progressions considered in relation to dimensions such as dependence/autonomy, isolation/coverage and task decontextualisation/contextualisation (Monereo, 2010).

Teaching resources were used as exemplifications in the initial training period (corresponding to the 2019/2020 academic year) and designed *ad hoc*, including teaching guides and class materials, among others, which address specific topics relating to physical-chemical processes.

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Appendix 1 includes a support file for teachers to prepare the educational guide for their school project. In it, and associated with promoting their competence in teaching design and planning, they identify the selected teaching approaches, the curricular elements that their proposal would contemplate, and the implementation and processes of metacognition and reflection that the intervention can offer.

Subsequently, throughout the second and third years, teachers created their STE(A)M proposals with the mentoring of the researchers, preferably focusing their projects on important topics aligned with the Sustainable Development Goals (SDG) of the 2030 Agenda (Schleicher, 2018), such as projects relating to health and wellbeing, sustainable cities and communities, and climate action, on the whole.

With the experience accumulated following the development of the IndagaSTEAM Escuela project over the last three academic years and considering the mutual interaction between what teachers do and what they think (Ariza et al., 2021; Garcia et al., 2019), this research analyzes the challenges and opportunities of the training received manifested in teachers' beliefs about STE(A)M education and in their teacher self-perception of their teaching in relation to the incorporation of integrating STE(A)M proposals.

Participants

The longitudinal case study presented here focuses on the involvement of two of the teachers from the third cycle of Primary who took part in the training programme and completed the entire process over the three years of the duration of the project in addition to using all of the research instruments set out in its development. This was a convenience sample in which the teachers participated in the research on a voluntary basis. They authorised the researchers to observe their classes, interview them, and use the reports and other teaching materials they designed during the training programme for the purposes of the research. Of course, these teachers are not representative of all primary school science teachers, and this might be considered a limitation of the study; however, they are representative of a sector of the teaching staff who show interest in their training and in taking on the challenges of reforming school science curricula (Organic Law, 2020).

Teacher 1 (from now on, T1) had 33 years of teaching experience after obtaining the academic Degree in Primary Education. T1 had carried out previously, and throughout its long history, numerous educational innovation experiences (the majority focused on the use of new technologies). This teacher also had previous experience collaborating on research projects at the University of Málaga and assumed responsibility for the centre's school management. For her part, teacher 2 (from now on, T2) had 12 years of teaching experience and the same academic degree as T1. However, unlike T1, T2 only had one experience in educational innovation and research projects.

Instrument

The implementation of the IndagaSTEAM Escuela project focused on teaching practices in terms of the STEAM community, STEAM integration, and STEAM assessment using the approach of the collaborative training model for professional development in schools, in which the teaching accompaniment began in the 2019/2020 academic year, with an introduction to the driving approaches of the project (inquiry, contextualisation and STE(A)M) and a mentoring of the training progression in the successive academic years 2020/2021 and 2021/2022, with design and implementation of our own projects.

Different research instruments were applied throughout this training process. Figure 2 shows a summary of the data collection timeline.

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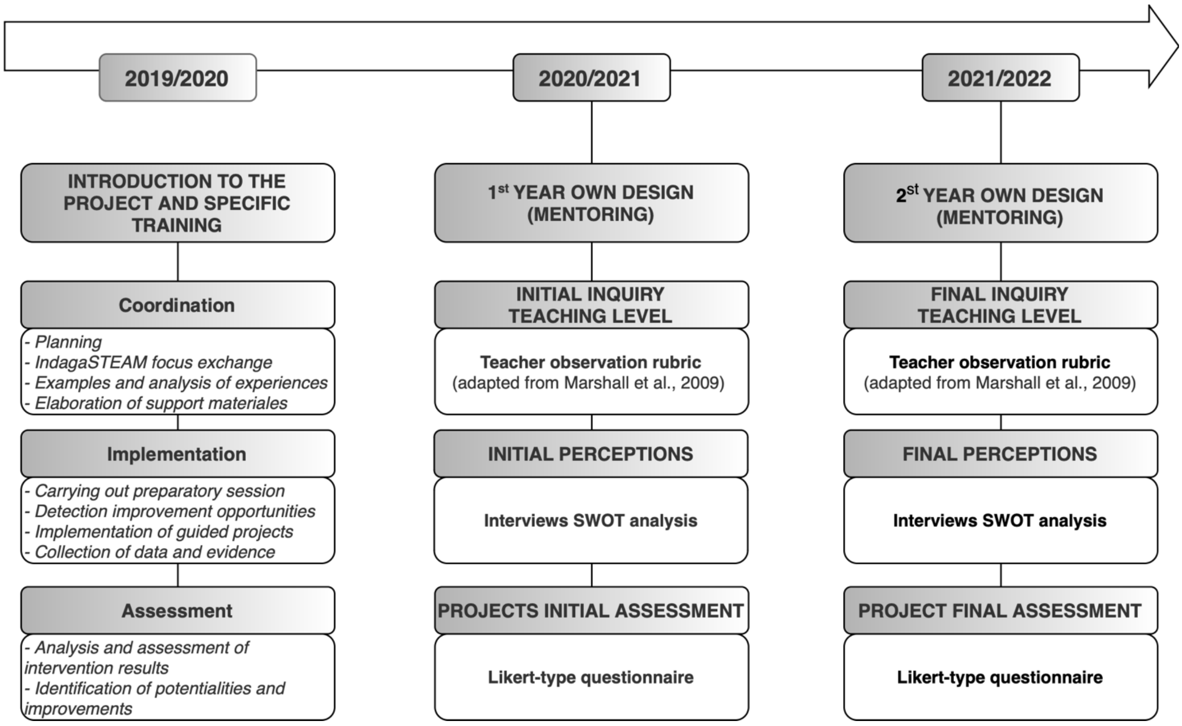
Figure 2
Chronology of IndagaSTEAM Escuela Project and Data Collection Instruments



Thus, the researchers and authors of this article who acted as observers during the workshops applied a rubric adapted from the EQUIP instrument by Marshall et al., (2009) (Appendix 2), which recorded the evolution of the level of teaching inquiry. Using a 4-point Likert scale (level 1: pre-inquiry; level 2: inquiry under development; level 3: competent inquiry and level 4: exemplary inquiry), the rubric covers aspects referring to the necessary skills and competencies for implementing this educational approach in the Primary Education classroom, such as the teaching role (in its action as a facilitator or guide of the teaching-learning process), communication strategies (as regards capacity to foster dialogue more or less guided by students) and class interactions (in relation to capacity to afford continuity to questions and answers arising during inquiry through argumentation), among others. This rubric was applied in the academic years the proposals were implemented, 2020/2021 and 2021/2022.

Additionally, semi-structured interviews were carried out, designed *ad-hoc*, with open-ended questions. A SWOT (Strengths, Weaknesses, Opportunities and Threats) matrix was applied for the design of the questions, an analytical technique with business origins that is simple to use and provides an excellent tool for evaluating reality and making decisions. Thus, it was possible to group the interview questions, which were organised randomly, into four categories to analyse external aspects (Weaknesses, Strengths) and internal ones (Threats, Opportunities) (Figure 3).

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Figure 3
SWOT Matrix Interview Structure

STRENGTHS	WEAKNESSES
What specific aspects can projects help you in your science classes?	What teaching shortcomings do you find in carrying out the projects?
What expectations do you have for the implementation and evaluation of the projects?	What external difficulties are you encountering in the design and implementation of the projects?
OPPORTUNITIES	**THREATS**

Finally, and with the aim of offering a more detailed view of the context of the intervention, two questionnaires with a 5-point Likert scale were provided, orientated towards discovering both the valuation of the projects designed and implemented by the participating teachers (questionnaire 1) and the working methodology established via the collaboration agreement between the Early Childhood and Primary Education Centre involved and the University of Málaga (questionnaire 2). Tables 1 and 2 show the statements formulated in the first **(S1-S8)** and second **(S9-S15)** questionnaires, respectively, and were grouped into categories aligned with the challenges and opportunities described by Margot and Kettler (2019) related to *teaching collaboration*, *curriculum*, *institutional support*, *methodology*, *professional development, teaching projection* and *student concerns.*

Table 1
Questionnaire 1

	Statements	Category*
S1	The strategies used in this project have stimulated the effort of my students and promoted their ability to learn by themselves and with others.	Student concerns
S2	The contents that have been worked on in this project are interesting for applying the Primary Education curriculum to issues of interest to my students.	Curriculum
S3	The realization of this project has meant an improvement in my students' learning.	Student concerns
S4	Carrying out this project has meant an improvement in the coexistence relations of my students with their families, the immediate environment, the teachers and our school.	Methodology
S5	Working on science through the strategies of this project represents an important methodological change in my science class.	Methodology
S6	The design of the materials used in this project has allowed me to create useful teaching situations for my students' learning.	Student concerns
S7	The implementation of this project has helped me reflect on my teaching practice.	Professional development
S8	The scientific projects set aside with these methodological guidelines as support material have helped me to connect the aspects of the curriculum, and it is useful to plan the evaluation of the students.	Curriculum

*Following Margot & Kettler's (2019) categorization

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Table 2
Questionnaire 2

	Statements	Category*
S9	Participating in this collaboration with the university has met my initial expectations.	Teaching collaboration
S10	The relationships established between the participants in the project have facilitated putting into practice active teaching strategies in my class.	Teaching collaboration
S11	The resources and strategies provided by the project have been of practical use for my classes.	Professional development
S12	Using questions about specific situations in students' daily life is a practice that helps students improve their knowledge about the processes that occur in them.	Curriculum
S13	The collaboration has been adjusted to the training levels of the participating teachers.	Professional development
S14	The collaboration has promoted spaces for communication and reflection	Professional development
S15	Overall assessment of your expectations achieved with the project.	Teaching projection

*Following Margot & Kettler's (2019) categorization

Data Analysis

The interviews were registered on paper and then analysed by the researchers who authored this article, experts in Experimental Science Teaching and teacher training. They were analysed qualitatively using coding techniques carried out with the software program Atlas.ti (versión9.0.20.0) (www.atlatsti.com). The researchers and co-authors of this work read the registries a number of times and identified common aspects within each of the established categories.

For the Likert-type questionnaires, a quantitative descriptive analysis was carried out with the program RStudio (version 1.3.1093), comparing the score averages that teachers awarded for each question, initially during the 20-21 academic year and on finalising the involvement during the 21-22 academic year. As the questions from both questionnaires were formulated in the affirmative, it has been considered only those that were found in the category "agree" and "completely agree" categories to be affirmative responses.

Research Results

Teaching Inquiry Profile

The results obtained regarding the teaching inquiry profile in the 2020/2021 academic year (Table 3) show an initial level of *inquiry in development* (with an average score of 1.96 out of 4.00 points). As favourable aspects, those related to the dynamic of the debates established particularly stand out, in which the teachers managed to successfully involve their students through open questions (average of 2.50), or their teaching role in the inquiry processes, in which they occasionally acted as facilitators (average of 2.25).

Table 3
Results of the Initial Level of Teaching Inquiry

Assessed actions	*M (SD)*	Level of teaching inquiry
Educational strategies	1.75 (0.71)	Developing inquiry
Order of instruction	2.00 (0.00)	Developing inquiry
Teacher role	2.25 (0.71)	Developing inquiry
Student role	1.50 (0.71)	Developing inquiry

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Assessed actions	*M (SD)*	Level of teaching inquiry
Questioning ecology	2.50 (0.71)	Proficient inquiry
Communication pattern	1.75 (0.00)	Developing inquiry
Classroom interactions	2.00 (1.41)	Developing inquiry
Global	1.96 (0.61)	Developing inquiry

Notwithstanding, the panorama observed throughout the 2021/2022 academic year was considerably more satisfactory (table 4). In the progression of the training framework of the project, it is in this last year that the teachers took on the role of "teacher as a designer", and from this, advances are observed in specific teaching domains, such as the level of *competent inquiry*, with the evolution of both teachers standing out in aspects related to their role of facilitators and not just drivers of the process, and in the contextualisation of tasks, strategies and the order of instruction assumed, which now favour environments aimed at student autonomy for tackling investigations and exploring their own ideas.

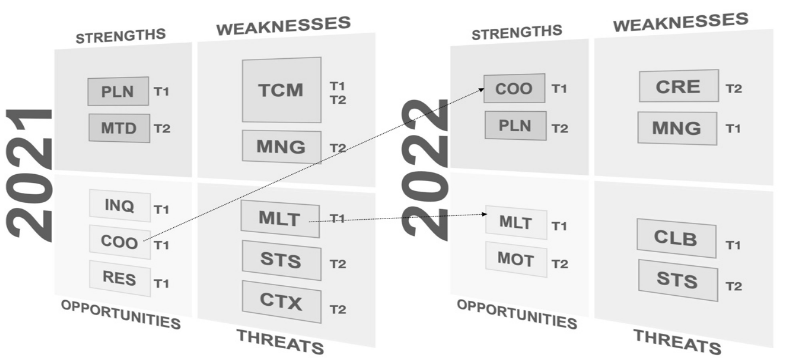
Table 4
Results of the Final Level of Teaching Inquiry

Assessed actions	*M (SD)*	Level of teaching inquiry
Educational strategies	3.50 (0.71)	Exemplary inquiry
Order of instruction	3.00 (1.41)	Proficient inquiry
Teacher role	3.00 (0.00)	Proficient inquiry
Student role	2.00 (0.00)	Developing inquiry
Questioning ecology	2.50 (0.71)	Proficient inquiry
Communication pattern	3.00 (0.00)	Proficient inquiry
Classroom interactions	2.00 (0.00)	Developing inquiry
Global	2.71 (0.40)	Proficient inquiry

SWOT Analysis

Figure 4 shows the result of the SWOT analysis comparison for the ends of the 2020/2021 and 2021/2022 academic years. It collects the identification codes for each of the arguments that teachers T1 and T2 gave globally to the questions indicated above.

Figure 4
Longitudinal Comparison of the SWOT Analysis for the Global Participants



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Thus, in 2021, within the analysis of internal factors, amongst the weaknesses stated, both teachers coincided in highlighting the lack of teaching skills in the conceptualisation of the *STE(A)M approach* (TCM), with T2, in addition, drawing attention to this section to *time management* (MNG). In contrast, the strengths put forward include *teaching planning capacity* (PLN) for T1 and *methodology* (MTD) for T2. Furthermore, in the analysis of external factors, T1 contemplates the *multidisciplinary nature* of the projects (MLT) as a threat, whereas T2 identifies *contextualisation* (CTX) and *student skills* (STS) in this category. T1 was the only one of the two who specified opportunities, explaining the development of *inquiry skills* (INQ), the improvement of student *learning results* (RES) and the advantages associated with the *cooperative scenario* offered by these types of projects (COO).

Following this, in the year 2022, it was observed how in the internal factors analysis T1 considered *time management* (MNG) as a weakness, whereas T2, after the projects had been carried out, identified a lack of *creativity* (CRE) for their development. Regarding strengths, it is worth mentioning the fact that T1 describes the *cooperative scenario* (COO), something that in 2021 she considered to be an opportunity, and which it seems finally materialised. For her part, T2 continued to consider *teaching planning capacity* (PLN) as a strength. In the external factors analysis, the threats expressed are lack of *teaching collaboration* (CLB) and *student skills* (STS), by T1 and T2, respectively. It is worth highlighting how in the opportunities expressed in 2022, T1 now mentions the *multidisciplinary nature* of the projects (MLT), something that in 2021 was perceived as a threat, while T2 regards student *motivation* towards learning (MOT) as a positive aspect.

With the aim of illustrating some of the responses provided by the teachers, Table 5 shows the emergent analysis codes, along with a small exemplification of the arguments given.

Table 5
Examples of SWOT Analysis Coding

SWOT Category	Code	Example
Strengths	Cooperative Scenario (COO)	T1 "I highly value the cooperative and participatory aspect that projects have."
	Teaching Planning (PLN)	T2 "Be able to choose the line of research and plan one's own work so that it is effective in student learning."
Weaknesses	Time Management (MNG)	T1 "One of the weaknesses found is my time management to develop projects."
	Creativity (CRE)	T2. "It's hard for me to focus and find good ideas."
Opportunities	Multidisciplinarity Nature (MLT)	T1 "In my case, it has helped me to have a more global and interdisciplinary vision of science."
	Motivation (MOT)	T2 "Make the classes more practical and attractive for the students."
Threats	Teaching Collaboration (CLB)	T1 "The main difficulty encountered has been the lack of collaboration from my teaching team in the classroom."
	Student skills (STS)	T2 "In some cases, the students do not see the importance or are not sufficiently prepared/motivated, and this can spread to the rest of the group."

Teaching Perception of Indagasteam Escuela Project and Collaborative Framework

The results of the quantitative analysis of Questionnaire 1 for teachers T1 and T2, referring to the design and implementation of the projects, are shown in Figures 5 and 6, respectively. This analysis showed that both teachers considered that the driving strategies of the intervention employed in the design and implementation of the projects developed signified an important methodological change in their science classes (**S5**), at the same time as permitting the stimulation of the efforts of their students and promoting their learning and that of their classmates (**S1**). Likewise, both considered that the implementation of their projects encouraged them to reflect on their teaching practice (**S7**), although T2 did not consider that it improved the learning of her students (**S3**) or

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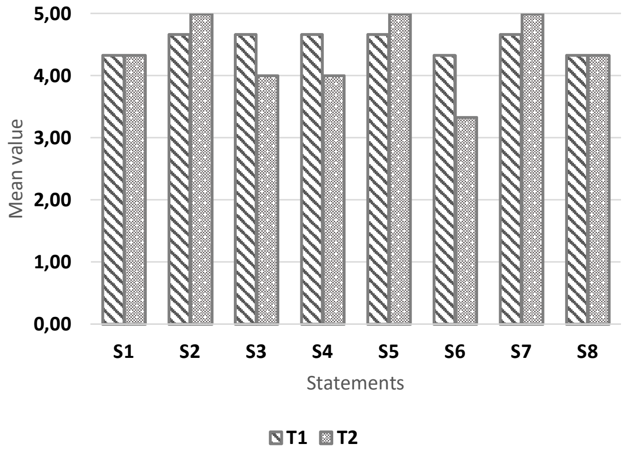
how they related to each other in class (**S4**), in contrast to T1.

Both considered that the materials provided as support for the design of the projects were of great help for the design phase, especially for establishing connections between curriculum and evaluation planning (**S8**). T2, however, did not find those materials of her own design useful for creating learning situations with her students (**S6**), unlike T1.

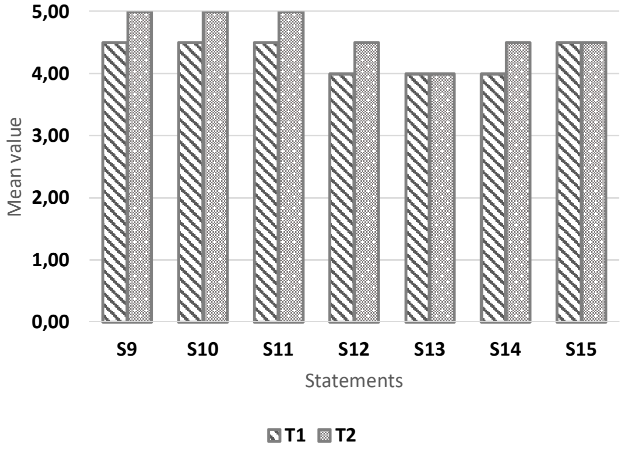
Lastly, both afforded great value to the contents worked on in the projects, given they were interesting for applying the curriculum to Primary Education in matters of interest for their students (**S2**).

Figure 5
Results of Teacher Perceptions of Projects



Regarding the valuation of the established collaborative methodology, both teachers stated that the communication spaces promoted (**S14**), relationships established (**S10**), and resources and strategies provided (**S11**) enabled the transfer of the driving strategies of the project of collaboration and improved throughout their development, being of practical use for their classes. In this regard, in the comparison between the two, there is a higher score for T2 than for T1 for the indicated items. Nevertheless, it should be pointed out that T2 did not consider improvements in the adjustment of the methodology of the project to her training level (**S13**), in contrast to T1.

Figure 6
Teacher Perceptions of Collaborative Framework



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Discussion

The educators in the study, Primary Education teachers, faced a number of different challenges in order to conceptualise, design and apply their vision of the STE(A)M approach through the use of inquiry and project-based work. To do so, they were provided with a particular strategy of active progressive training over the duration of the project. The teacher involvement fosters their self-efficacy and their beliefs, sustained in different degrees of scaffolding in STE(A)M teaching domains (Margot et al., 2019; Roehrig et al., 2021; McLure et al., 2021) associated with tensions as regards tackling curricular integration, and teaching methodologies orientated towards problem-solving and situated learning of their students. The data obtained show different achievements in some personal domains, such as the level of competent inquiry reached when implementing the STE(A)M projects they designed and a considerable improvement in the methodological change incorporated, increasing the degree of autonomy provided to their students.

In response to the first research question raised, a number of satisfactory results have emerged, given the short implementation time of the IndagaSTEAM Escuela project. This is deduced from the evolution observed by the researchers/co-authors of this study as regards the teaching inquiry profile of T1 and T2, which evolved positively from *developing inquiry* to *competent inquiry* (Marshall et al., 2009), facilitator of autonomous and active learning in students. Yet, there is still a perception of a certain failure to take advantage of unplanned learning moments, with a lack of exploration of ideas and questions arising throughout the projects, something also confirmed with the perception obtained in statement **S3**, which fails to reach positive levels for T2. This could be identified as one of the teaching tensions described in the literature, related in this case to methodological aspects (Margot & Kettler, 2019). However, it could be seen how there is an improvement in the degree of autonomy provided to students (**S1**) and in the methodological change incorporated (**S5**), with positive teaching perceptions for both educators. Finally, some pleasant results confirm how they positively value the relationships established with the different actors (**S4**), and the processes of reflection promoted (**S7**), all of which are aspects closely related to the incorporation into the inquiry-based teaching profile, a driving approach for the projects.

Relative to the second research question about their perception regarding advantages and difficulties encountered in the projects, there is an equivalent behaviour regarding a series of aspects at the implementation level and the established collaborative framework. In contrast, in others, the teachers show different progression.

Concerning the advantages, throughout the experience, the teachers recognized them in aspects related to *teaching planning capacity* (PLN) and *cooperative scenarios* offered by these types of projects (COO). In contrast, factors associated with *methodology* (MTD), development of *inquiry skills* (INQ), *multidisciplinary nature* of the projects (MLT) and student *motivation* towards learning (MOT) show different considerations.

Thus, in 2021, within the internal factors analysis, the strengths put forward include *teaching planning capacity* (PLN) for T1 and *methodology* (MTD) for T2. On the other hand, T1 specified opportunities, explaining the development of *inquiry skills* (INQ) and the advantages associated with the *cooperative scenario* offered by these types of projects (COO). Following the year 2022, the internal factors analysis T1 considered strengths, the *cooperative scenario* (COO), something that in 2021 she considered to be an opportunity, and which it seems finally materialized. T2 continued to consider *teaching planning capacity* (PLN). In the external factors analysis, the opportunities expressed in 2022, T1 now mentions the *multidisciplinary nature* of the projects (MLT), something that in 2021 was perceived as a threat, while T2 regards student *motivation* towards learning (MOT) as a positive aspect. Considerations that base their assessments on the conductive strategies of the intervention project used in the design and implementation of the projects developed, as promoters of an important methodological change in their science classes (**S5**), at the same time that they allowed to stimulate the effort of their students and promote their learning and that of their classmates (**S1**).

Likewise, the assessment of the collaboration methodology established in the project was considered by both teachers, useful for their classes, recognizing the interest in the communication spaces promoted (**S14**), the relationships established (**S10**), as well as the resources and Contributed strategies (**S11**) facilitated transferring the project's driving strategies.

Regarding the difficulties in the entire experience, they manifested themselves associated with *time management* (MNG) and *student skills* (STS). However, the conceptualization of the *STE(A)M approach* (TCM), the *multidisciplinary nature* of the projects (MLT) and c*ontextualization* (CTX), which are shown in the first year, give way to factors associated with *creativity* (CRE) and *teaching collaboration* (CLB) in the second. As a specific behaviour,

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in the analysis of external factors, T1 contemplated the *multidisciplinary nature* of the projects (MLT) as a threat, whereas T2 identified *contextualization* (CTX) and *student skills* (STS) in this category.

Following this, in the year 2022, it was observed that in the internal factors analysis, T1 considered *time management* (MNG) as a weakness, whereas T2 after the projects had been carried out, identified a lack of creativity (CRE) for their development. In the external factors analysis, the threats expressed were lack of *teaching collaboration* (CLB) and *student skills* (STS) by T1 and T2, respectively. It is worth highlighting how, in the opportunities expressed in 2022, T1 mentioned *the multidisciplinary nature* of the projects (MLT), something that in 2021 was perceived as a threat, while T2 regarded student *motivation* towards learning (MOT) as a positive aspect. Regarding the project strategies, T2 did not consider improvements in adjusting its methodology to their educational level (**S13**), unlike T1.

This evolution of teacher perceptions reflects behaviours collected in other experiences described in the literature, evidencing that if teachers verify in the classroom that the methodological change positively affects students, their beliefs are modified, and their perception of self-efficacy increases, enabling them to continue introducing changes in their teaching practice (Ariza et al., 2021; Roehrig et al., 2021).

Conclusions and Implications

This study has presented a training experience for the STE(A)M education scenario, analysed as a case study, from a model of school cooperation sustained with the support of university researchers, developed over the course of three academic years in a public early childhood and primary education centre. Concretely, the study shows how the STE(A)M approach promoted has been used to inform school practices and teachers' professional development efforts. Contested aspects in STE(A)M education, such as which level of integration of the inquiry approach is desirable, what the role of disciplinary content knowledge is in STE(A)M, or how much focus to accord to the development of skills, among others, emerged in these different accounts. The impact of the program on teachers' beliefs and practices, as well as its effect on teachers' self-efficacy to implement the STE(A)M scenario, are also discussed.

The longitudinal study carried out employed a diverse selection of instruments for data collection throughout the process (rubrics evaluation, ad hoc interviews and Likert-type scale questionnaires). The methodology for their treatment and subsequent analysis has permitted us to discover the levels reached by the teachers as regards the use of inquiry and its evolution, along with their perceptions in respect of the achievements and difficulties that the collaborative scenario has offered to their students and their performance.

From a global vision, the STE(A)M education panorama implies substantial changes concerning the teaching practice, curriculum, school organization, professional development models, and teaching materials, among others. All the initiatives are essential in conceptualizing and clarifying educational purposes and methodologies.

Whatever perspective was selected (STS, PBL or inquiry) is firmly based on what it is already known from Science, Engineering, or Mathematics education, with the addition of the potentiality and limits of disciplinary integration demanding intensive professional efforts closely linked to design, a high-order professional competence for teachers. A new focus with well-designed examples of STE(A)M curricular activities, adapting, and sequencing existing teaching and learning units could support progressive STE(A)M teachers' professional development. Otherwise, the systemic nature of STE(A)M education involves different levels of collaboration between educational administrations, educational research institutions, and teachers and schools.

Regarding STE(A)M teaching professional development, initiatives are needed to provide useful training approaches, with training progressions and adequate scaffolding so that teachers can conceptualize and clarify educational purposes to design relevant projects and implement them, addressing both personal and systemic challenges of educational institutions. As such, in Spain, there is a necessity of examples of research-based curricular proposals that can support teachers in the double effort of adopting the STE(A)M educational framework and implementing it adequately.

For this reason, selecting, adapting and sequencing existing teaching and learning units is highly necessary to apply and experience them successfully. This is even more the case if linking it to the "teacher as designer" model. For all of the above, still respecting due reservations, being a case study, this experience provides an interesting proposal for the professional teaching development of Primary Education teachers in the scenario of STE(A)M education for the Spanish context, being extrapolated to the present international scenario of STE(A)M education.

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Declaration of Interest

The authors declare no competing interest.

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