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Understanding Science Teachers' Integration of Active Methodologies in Club Settings: An Exploratory Study

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Abstract: This study analyses if school science clubs may serve as a resource to facilitate the introduction of active methodologies into science classrooms. Focusing on science clubs in Portuguese schools, this study aims to determine whether the teachers who coordinate and direct these clubs promote activities that incorporate aspects of problem-based learning and project-based learning methodologies. In order to do so, a series of semi-structured interviews were conducted with 20 teachers, and their responses were analysed using content analysis strategies. The results show that although they do not explicitly refer to the use of these methodologies, teachers do propose the implementation of projects within clubs, and they incorporate aspects of these strategies in the activities they conduct. In this sense, teachers appreciate the role of clubs in promoting these types of strategies (PBL y PjBL) and the facilities they offer for their implementation. Additionally, teachers believe that one can only learn how to do projects through practise, i.e., doing projects with their students, and they think that clubs offer an opportunity to develop PBL and PjBL methodologies in a context free from the responsibilities and constraints of the classroom.

Keywords: science clubs; active methodologies; project-based learning; problem-based learning; qualitative research; interviews; teachers' perspectives

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1. Introduction

Adapting educational systems to the scientific and cultural changes that occur in society, and improving their quality and effectiveness constitute two fundamental objectives of modern communities.

In this context, one of the crucial tasks of education must be to provide students with knowledge, as well as the competencies and attitudes they will need to navigate a changing and complex world, where traditional solutions are becoming less useful each day [1]. Therefore, over the last decade, numerous institutions have addressed the skills and dispositions that are expected to be vital for schooling in the 21st century [2]. Some of these skills are critical thinking, communication, autonomy, collaboration, and creativity, and adaptability, flexibility, interdisciplinary communication, and complex problem-solving are examples of competencies that will be required for the future [3].

Scientific education must also take responsibility for fostering the development of these skills in future generations of citizens. In this regard, as stated by Domènech-Casal et al. [4], science education advocates for a more contextualised and competency-based approach to science education [5], where student participation promotes their ability to apply, transfer, and create scientific knowledge.

This same perspective is also evident in works such as those of Lee et al. [6], and it translates into an educational approach in which the essential focus is no longer on having "specific knowledge" of mathematics, science, or technology, but on being able to confront specific situations or problems in real contexts, thinking and acting as scientists, mathematicians, or engineers would [4]. Furthermore, some of these 21st-century skills, such as critical thinking and problem solving, effective communication, collaboration and team building, creativity, and innovation, have been identified as important skills that enable students to improve their understanding of science [7].

In light of these circumstances, active methodologies such as inquiry [7], problem-based learning (PbBL), and project-based learning (PjBL) are regarded as strategies that facilitate learning and the development of 21st-century competencies and skills [2,8–11]. These methodologies support the cultivation of critical thinking [12] by encouraging problem solving and the integration and application of knowledge in authentic contexts and tasks [13].

However, the inherent characteristics of these methodologies sometimes make it challenging for teachers to introduce them into the classroom. As a result, a potential alternative that arises is the use of non-formal spaces. The main objective of this study was to examine whether teachers who coordinate science clubs proactively implement active methodologies in these clubs.

This study aims to explore the voluntary adoption and integration of active instructional strategies by teachers within the club context. By investigating teachers' practises and approaches, this study seeks to gain insights into the extent to which active methodologies are employed in club activities and the factors that influence their implementation.

2. Theoretical Framework

2.1. Shifting Gears: Introducing Active Methodologies in Science Education

As can be inferred, the response to contemporary educational and social demands involves a revision of how science is taught in schools. This revision should lead to the design of suitable strategies for today's society and redefine the teaching model so that the development of skills is linked to the acquisition of scientific, technical skills. According to many experts, although traditional methods of direct instruction and recitation may be effective for acquiring factual knowledge, 21st-century skills require new pedagogical approaches [2].

Therefore, the history of education is filled with calls to make student learning more active and shift the focus from the memorisation of information to the utilisation of information [9]. The landscape of teaching and learning in schools is rapidly evolving, as educators continue to seek innovative approaches that adapt to the characteristics of 21st-century societies, life, and students [14]. This is evidenced by the paradigm shift observed over the past decades, where education professionals have re-evaluated the approaches that should be adopted in schools. In particular, there is now a recognition of the role that informal or non-formal learning opportunities can play, and there is a transition from a teacher-centred pedagogy, characteristic of traditional models of teaching and learning [15], which views the process as a transmission of knowledge, to a student-centred pedagogy built upon the constructivist principles of learning, where students "learn by doing and reflecting on what they have done and what it means" [16].

These calls have attracted significant interest since the beginning of the 21st century [17]. Initiatives developed throughout Europe actively pursue the renewal of science education and the implementation of active learning methodologies. Examples of such active methodologies include inquiry-based pedagogical strategies like project-based learning (PjBL) [8,18–20].

Implementing active methodologies is a complex process that requires a paradigm shift, necessitating schools to review their vision and mission, and teachers and students to change their perspectives on science education [21]. For instance, in contrast to traditional lecture-based education, active learning significantly reduces teacher-centred instruction, and students are expected to actively seek knowledge from various sources [21].

Despite the challenges in implementing active methodologies, it is recognised that the types of activities typically implemented when students engage in active methodologies (e.g., students formulating their own questions following a reading assignment, students participating in peer discussion, or students working collaboratively/individually on complex problems) are the most effective in promoting student learning and addressing student affect (i.e., learning attitudes and motivation) in the subject domain [22].

Indeed, there is ample evidence that active learning is an effective way to improve learning and student performance in subjects such as science and mathematics compared to passive lectures. For example, the meta-analysis conducted by Freeman et al. [23], in which the authors reviewed 225 different studies focused on various STEM subjects (biology, chemistry, computer science, engineering, geology, maths, and physics), showed the benefits of active learning approaches in outcomes such as exam performance, even when the studies were conducted in different contexts, classes, educational levels, and so on [24]. Furthermore, both these studies and others indicate that active methodologies support the effectiveness of active learning for student engagement and performance in STEM fields.

Freeman et al.'s [23] meta-analysis provides strong evidence supporting the adoption of active learning strategies, as opposed to traditional lectures, in order to enhance the academic performance of undergraduate STEM students [22]. However, for these benefits to occur, it is essential to make students aware of their role in active learning as opposed to the teacher's role, because students, who may be new to this way of learning, might not even perceive such learning as normal [25].

In general, most methodologies grouped under the umbrella term "active methodologies" are based on a conceptual framework developed around concepts such as constructivism, which proposes that knowledge is actively constructed by the learner. For example, constructivism considers that learning is deeper and easier to transfer to new situations when it is contextualised [4]. Similarly, Beier et al. [24] proposed that students "learn and apply important ideas in a discipline" while engaged in a driving question (p. 318). The most common and prevalent active methodologies in science education are problem-based learning (PbBL) and project-based learning (PjBL). These methodologies, frequently situated within the framework of inquiry-based teaching strategies (IBL), offer valuable opportunities for students to actively engage in their learning processes. PbBL and PjBL foster a student-centred approach, allowing learners to delve into real-world problems and projects, encouraging critical thinking, collaboration, and the integration of knowledge across disciplines. By embracing these active methodologies, educators can cultivate a deeper understanding of scientific concepts and nurture the development of the essential skills needed for success in the modern world.

2.2. Problem-Based Learning (PbBL): An Overview

The concept of PbBL has gained international recognition and evolved to a point where there is no single consistent and universally agreed definition [8]. Instead, multiple, and sometimes contradictory, conceptualisations exist [26]. Merritt et al. [9] conducted a systematic literature review and concluded that there are multiple theoretical sources for researchers' definitions of PbBL. Nevertheless, following these authors, PbBL can be defined as the art of problem solving, a learning approach that challenges students with ill-structured problems that serve as stimuli for learning [12]. Therefore, it is an instructional approach that places students at the centre of the learning process by presenting them with real-world, complex problems or scenarios that reflect authentic challenges within the subject domain, but also require going beyond disciplinary knowledge to integrate and apply it in the resolution of specific problems [12].

In brief, PbBL is a student-centred pedagogy that stimulates students with authentic, ill-structured problems through which they can acquire new knowledge, while teachers act as facilitators. However, when the literature is reviewed, it has been found that PbBL is not perfectly characterised and structured. Specifically, as stated by Sukackė et al. [21], depending on the sources consulted, it can be concluded that the implementation includes six stages [27], five stages, or sometimes three stages [12]. The complete process can be summarised as follows: (1) identifying and understanding the problem, (2) collecting potentially useful information to solve it, (3) agreeing on a possible solution, and (4) reviewing the proposed solution. Once again, following Sukackė et al. [21], this general framework is reflected in a series of specific characteristics, including:

1. Ill-structured, open, real, and unstructured problems are drivers, motivations, and frameworks for learning.
2. Problem identification and resolution serve as a vehicle to acquire knowledge, develop different types of skills, and consequently achieve (learning) goals. Thus, the learning process is self-directed and collaborative, but also exemplary, contextual, experiential, and reflective.
3. Teachers become facilitators and "scaffolders".

Therefore, the distinct essence of an effective problem-based learning process lies in its reiterative and reflective characteristics, which allow for the creation of a knowledge-building environment. Reiteration enables students to review their prior thought processes about a problem and discuss how they would modify their ideas and possible solutions based on the new knowledge they obtained through self-directed learning [11]. In summary, an effective PbBL process is composed of a sequence of learning activities that are reiterative and reflective, involving far more than acquiring the facts and concepts to be recalled.

These distinctive characteristics translate into a series of benefits for students when introduced into the classroom. For instance, PbBL is often associated with positive student learning experiences [28]. Specifically, by using real-world applications, students tend to have a higher level of motivation to participate and engage with the material [29]. A critical point highlighted in the literature is that students engaged in PbBL sequences are motivated by finding a solution rather than gaining a clear understanding of the task, and they tend to adhere to relatively rigid structures and minimise effort when facing unfamiliar and ill-defined problems [21].

Furthermore, when working with methodologies such as PbBL, students show similar or better conceptual gains compared to traditional lecture courses [28]. In this regard, studies indicate that PbBL also increases knowledge retention, conceptual development, and academic achievement [9], and facilitates interdisciplinary thinking towards an integrative perspective and a holistic approach to scientific and practical solutions [30].

Finally, students learn to work in professional teams, with each member bringing different skills to solve the problem [28]. Additionally, PbBL can support the development of "soft" skills [30], such as research skills, negotiation, teamwork, reading, and writing, and contributes to the improvement of communication skills [31]. In conclusion, the problem-based learning approach facilitates the teaching of both essential knowledge and transferable skills beyond the classroom [12].

2.3. Project-Based Learning (PjBL): Definition and Overview

As with PbBL, there are also multiple definitions of project-based learning (PjBL), as researchers have defined it in various ways over the years [24]. However, most of these definitions agree that it is a student-centred teaching methodology that organises learning around the development of projects contextualised in real-world problems that are meaningful to students. The most notable characteristic of project-based learning is the requirement for the development of a product intended for an audience [20,32].

In this regard, PjBL is an inquiry-based [33], active, and experiential learning approach [23], in which the central element of the process is the development of a project. Thus, PjBL engages students in activities such as design, problem-solving, decision-making, and research [34], enabling them to integrate, apply, and construct knowledge as they work together [8,20]. Furthermore, it is described as a teaching method that is open-ended and provides limited guidance from the teacher, offering ample opportunities for acquiring higher-order thinking skills [2].

PjBL finds its pedagogical foundation and starting point in constructivist premises, based on the transformation and construction of knowledge. Specifically, projects focus on issues that lead students to confront and deal with the key concepts and principles of a certain discipline [34], mobilising their theoretical and technical knowledge to find solutions [21].

As previously indicated, PjBL is a learner-centred learning process in which students investigate a question through enquiry, with benchmark lessons and milestones along the way [35]. Project-based learning is a system developed to encourage students to take more responsibility for their education and learning, as they need to solve problems by defining them, discussing ideas, designing enquiries, collecting and analysing data, and sharing findings with their peers [32]. Therefore, students have a high degree of responsibility, autonomy, and unsupervised work time when engaging in projects [33].

However, ambiguity remains among researchers regarding the exact key characteristics or core features of PjBL [8]. The essential elements of PjBL may vary, but there are substantial overlaps among several of those elements [8,11,20,24,36], which normally include the following:

1. PjBL projects are authentic in terms of topics and contextualised in such a way that the learner is working on authentic or real-world problems. As Daddysman et al. [28] indicate, "a key tenet of PjBL is that the project must be real and important and something that a professional would actually do or consider".
2. Everything begins with challenging scientific problems and questions, which act as driving questions that anchor student learning. Thus, as Aksela and Haatainen [13] pointed out, the distinctive feature of project-based learning is problem orientation, that is, the idea that a problem or question drives learning activities.
3. Learners control the learning process, which allows decisions regarding pacing, sequencing, and the actual learning content. In other words, they have voices and choices.
4. Students are engaged in scientific and disciplinary practises, such as investigations in which they can conduct sustained enquiries. They also participate in benchmark lessons and activities.
5. There is a focus on defining appropriate learning goals that lead to deep understanding [9].
6. There are ample opportunities for student reflection, critiques, and revisions. Additionally, it is common to provide feedback and various types of scaffolding to the students throughout the process.
7. Social structures are developed that promote participation and collaboration among students.
8. The project results in the students developing a final product or artefact.

Of these characteristics, the two most distinctive are (1) the fact that projects require a driving question or problem that serves to organise the project activities [32], and (2) that the activities should result in artefacts that culminate in a final product that addresses the driving question [12].

Regarding the driving question, according to Krajcik and Czerniak [37] and Wilhelm et al. [18], it should be feasible (i.e., an investigable question) and sufficiently open-ended that the results are not predetermined and allow for student choice and variability [35] so that they can develop their own approaches to develop the product or artefact.

On the other hand, the construction of the artefact is critical; through this process, students construct their knowledge [13], as it helps learners integrate and reconstruct their knowledge, discover and improve their professional skills, and increase their interest in the discipline and their ability to work with others [20]. Thus, the final products are concentrated expressions of various competencies that students may develop during PjBL. These artefacts are representations of students' solutions resulting from the activities used to address the driving question [32], and can take the form of physical objects, models, documents, such as reports, and multimedia, such as videotapes and computer programmes.

Although this study did not intend to focus on the impact of PjBL on student learning, a small number of studies have demonstrated that PjBL brings benefits in terms of students' content knowledge, learning strategies, skills, and motivation (see, for example, Guo et al.'s meta-analysis [20]). However, more evidence is needed regarding how and when PjBL is the most suitable. In general, it is recognised that PjBL provides student-centred, culturally relevant, and contextualised learning opportunities [19], enabling teachers to tailor instruction to their students and promote students' ability for self-directed learning [36].

Similarly, different studies [24,35,38] have indicated that the introduction of PjBL in the classroom positively affects students' interest, enthusiasm, and motivation. In this regard, PjBL creates opportunities for students to take initiative in the learning process and tackle relevant real-world problems independently and in teams, contributing to increased student engagement, commitment, and self-efficacy.

The involvement in these projects offers a suitable occasion for building bridges between phenomena studied in the classroom and experiences in the real world [12], allowing students to employ their existing knowledge and combine it with the learning acquired throughout project development [21]. Therefore, researchers agree that PjBL contributes to a deeper understanding of key concepts and principles in disciplines, and an increase in students' content knowledge [22,26,37,39].

Within this framework, other studies have detailed how the introduction of PjBL methodologies can contribute to improving academic performance [8,32,39], specifically in STEM subjects [2].

Regarding students' skills, as mentioned, PjBL plays a relevant role in developing 21st-century skills such as communication, negotiation, collaboration, and teamwork [13,31]. Studies have also highlighted the contribution of PjBL to the development of "soft skills" and other skills, such as problem-solving [17], critical thinking [31], autonomy [4], and self-efficacy [33]. Finally, PjBL enables the development of science process skills such as the ability to organise work, plan, and manage time [34].

Entering the realm of affective aspects, the literature details how PjBL improves students' attitudes (see meta-analysis conducted by Guo et al. [19]) and their personal involvement and commitment in the learning process [4,33]. However, the most common results [32,36] focus on the effects of methodology on student motivation. In this regard, PjBL allows students to make certain decisions throughout the process, and to focus on aspects of the project that capture their attention and interest them most. Additionally, the problems they face in PjBL are usually relevant to the real world, which further enhances student motivation.

In summary, when thoughtfully designed and implemented, the evidence suggests that project-based learning can be more effective than traditional educational approaches and can provide various benefits for the students involved, both at cognitive, conceptual, and procedural levels, as well as at affective, personal, social, emotional, and motivational levels.

2.4. PbBL versus PjBL: Exploring the Shared Grounds and Distinctive Aspects

PbBL and PjBL share a series of characteristics and similarities [2,28] that often make it difficult to distinguish them from each other or clearly define their key characteristics [2]. As a result, both terms are often confused [24] and even used interchangeably by researchers and teachers [40].

However, it is true that there may be some overlap between the two strategies [21], as they are closely related, share a central goal, and are designed around complex and contextualised problems that allow students to operate relatively autonomously in order to construct solutions [24]. In this framework, both are described as active and student-centred educational methods that promote group work and knowledge construction, with teachers acting as facilitators of the learning process [40]. Similarly, both PbBL and PjBL employ open-ended problems that promote students' critical thinking and facilitate their understanding of scientific knowledge [28].

However, it is also true that PbBL and PjBL have some significant differences [2], such as the implementation time. While PbBL uses semi-structured problems that can last only a few class periods, projects in PjBL can last from a few weeks to a whole term or year, depending on the course and programme structure [28]. Although studies [28,30] have pointed out certain differences between the two methods, such as the different types of tasks, the key lies in the way knowledge is used [20].

The focus of PjBL is more on the mobilisation of knowledge to produce a final product [26], whereas PbBL is more oriented towards knowledge acquisition [21], emphasising the role of students in defining the problem and developing a solution [2]. Therefore, the main difference between the two methods is that in PbBL, the solution to the problem is merely suggested, whereas in PjBL, it must be executed. Thus, a significant difference lies in the fact that PjBL focuses on creating a "product" or constructing a concrete artefact [13,36].

However, since both strategies resemble each other in the pedagogical foundations, objectives, and rationale behind them, despite their differences in specific aspects of their implementation, this work has chosen to follow the steps of authors like English and Kitsantas [41], Merritt et al. [9], and Beier et al. [24], among others, and consider that PjBL constitutes a specific type of PbBL focused on a problem that involves the development of a product and culminates in the construction of an artefact.

2.5. Not a Walk in the Park: Challenges to Face When Introducing Active Methodologies

While active methodologies bring numerous benefits to the learning process, their implementation is not without its challenges, despite the widely recognised advantages and growing popularity they are gaining [12] and the enthusiasm shown by educators [11,42]. However, these challenges must also be considered:

1. First, active methodologies generally require more resources and can be costlier than traditional teaching methods [30]. For instance, they may require access to specific resources, spaces, or tools that are not readily available in all educational settings.
2. Second, a common criticism of these methodologies is that they require significant effort and substantial time investment from both teachers and students [43]. In this regard, the study by [32] illustrates how some teachers or parents might perceive that project-based methodologies consume large amounts of instructional time, with these extended time blocks covering only a small portion of curriculum content. Methodologies such as PjBL and PbBL require more time for planning and implementing activities than traditional methods. However, as demonstrated by previous studies [21], it is crucial for students to have this dedicated time to ensure positive learning outcomes.
3. Third, specific methodologies, such as PbBL and PjBL, require a deep understanding of the pedagogical foundations on which they are based. This poses a challenge for teachers, who may unintentionally use problem-based learning without realising that their teaching practises have essentially remained unchanged [12]. In fact, arguments from Mentzer et al. [44], Hasni et al. [45], and Wieselmann et al. [11] emphasise that teachers often mistakenly equate PjBL with hands-on activities that lack genuine purpose.
4. Finally, active methodologies often involve increased student engagement and collaboration. As mentioned previously, their implementation requires students to take responsibility for the learning process while receiving appropriate the support and tools to develop their projects. Therefore, the learning environment and teaching practises must be intentionally designed to support students' self-regulated learning. These two factors determine that managing group dynamics may differ from traditional classroom settings, which often require additional classroom management strategies and skills.

Within this scenario, a space is created that can be leveraged by non-formal scientific activities that, when appropriately integrated as a complement to the formal system, can offer clear opportunities to address this issue. Non-formal scientific activities provide valuable opportunities for the development of active methodologies, as they may not be subject to some of the typical limitations encountered in formal education, such as time constraints or curriculum restrictions. Therefore, by leveraging non-formal activities, educators can provide students with more enriching experiences that are often difficult to replicate within the confines of the classroom [46]. For that reason, the integration of non-formal contexts in learning and teaching has gained recognition as a vital component in science education, as evidenced by a wide range of studies [47–51]. These studies emphasise the significance of non-formal activities in fostering a holistic approach to science education and promoting deeper engagement with the subject matter. By acknowledging the role of non-formal contexts, educators can effectively leverage these opportunities in order to provide students with a well-rounded and impactful science education [47,48].

Building on these ideas, this study seeks to examine whether science club coordinators encounter the conducive conditions necessary for implementing active methodologies in science education.

3. The Study: Research Methods and Data Collection Procedures

This study is part of a larger research project focused on exploring the educational possibilities offered by the "Clubes de Ciência Viva na Escola" (The Alive Science Club at School) programme in contributing to science education from the perspectives of coordinating teachers. In this regard, the project aims to gather teachers' evaluations of the clubs themselves, their experiences participating in them, the benefits they provide to students, and, ultimately, their role in the teaching and learning processes of science.

Consequently, a qualitative approach was employed because it seeks to give voice to the participants and understand how they interpret their experiences [52]. Thus, this article reports a descriptive qualitative study in line with its intention to present, analyse, and provide a rich description of science teachers' subjective perceptions and experiences regarding school science clubs. The focus was on capturing the lived experiences of science teachers within the specific context of running a science club in their school.

This study emerged within the context of the broader project. In this regard, the findings described represent specific aspects that arose during the project's development and data analysis, and were not initially considered in the original design. Therefore, this study has an exploratory nature and it aims to investigate whether teachers overseeing science clubs proactively incorporate active methodologies in club activities.

3.1. Exploring the Context: Setting the Stage for the Study

This study involved science teachers and was conducted in the context of school science clubs. These clubs are part of the "Rede Nacional de Clubes Ciência Viva na Escola" (The Alive Science Club at School Network (https://clubes.cienciaviva.pt/, (accessed on 7 January 2024)). The primary objective of this network is to promote science literacy among students, integrate and connect different learning spaces in school (namely the classroom and the clubs), and foster innovative approaches to teaching science that provide students with widespread access to scientific practises through hands-on and minds-on methodologies.

The network encompasses a diverse range of schools across the country, with 897 clubs in 718 schools collaborating with various institutions such as universities, museums, and research centres. These partner institutions organise activities, present challenges, and offer resources. School science clubs operate as extracurricular projects within schools and are coordinated by science teachers affiliated with these institutions.

3.1.1. Participants

The participants were 20 teachers who are responsible for coordinating or running science clubs in their schools. They were selected based on their availability and interest in this study. This group of teachers was chosen because they were deemed best suited to provide insights, experiences, and reflections [53] on their roles as coordinators of the club. All participants were experienced science teachers with teaching experience ranging from 21 to 40 years and had at least one year of experience in running a science club. They were informed about this study's conditions and objectives, and were asked to sign an informed consent form.

3.1.2. Data Collection and Analysis

The data collection process involved conducting semi-structured interviews with the participants. The interview script was designed with open-ended questions to encourage participants to express their thoughts and experiences freely, allowing for detailed and comprehensive responses that would provide a deeper understanding of their perspectives and experiences.

Following ethical approval from the Comissão de Ética para a Investigação em Ciências Sociais e Humanas da Universidade do Minho (nº 101/2022) and the Ministry of Education (code 0843600001), the interviews were conducted face-to-face, enabling personal and interactive exchanges between the researcher and participants. Each interview was conducted separately for each teacher in the school. With the participants' consent, the interviews were audio-recorded and transcribed verbatim, in order to ensure the accurate representation of the data. The textual information collected from the transcriptions was then analysed using the basic principles of Content Analysis [54], employing a combination of strategies from Qualitative Content Analysis (QCA) [55,56] and Thematic Content Analysis (TCA) [57]. Content analysis was chosen to preserve the richness of the teachers' responses and to gain a deeper understanding of the diverse perspectives held by the participants.

The analysis was conducted inductively, with codes emerging directly from the data rather than being pre-established. The responses provided by the interviewed teachers were coded using semantic criteria based on the meanings of the participants' statements. Throughout the Results section, interview excerpts are presented to illustrate and exemplify the types of responses provided by the teachers. A code was attributed to each teacher to maintain anonymity.

For this reason, instead of sorting the teachers' perspectives into fixed categories, we opted for a storytelling approach. We aim to seamlessly blend various excerpts that genuinely represent the diverse viewpoints of educators. This method allows us to thoroughly explore the many aspects of teachers' perspectives, offering a deeper and more nuanced understanding of the challenges and successes in implementing active methodologies within science club coordination, thus providing a deeper and more authentic portrayal of the complex landscape surrounding teachers' experiences.

4. Results

Insights from Science Teachers in School Science Clubs

First, the interviews revealed how teachers value the role of active methodologies in science learning. Specifically, while acknowledging the existence of various types of active methodologies, the vast majority of teachers primarily associate them with project-based learning. This preference stems from the belief that project-based learning aligns with the ideal classroom approach (T15).

> *"In my point of view, the school should be like this. Students should learn through projects, not by subjects. Because we could connect several disciplines, right? And they would still learn the same content, but in a different way. However, there should be fewer students, right? And therefore, I would be satisfied if by the end of their schooling, students acquire the competencies outlined in the student profile, right?"* (T15)

In this regard, when teachers reflect on their vision of an ideal school, a key aspect that emerges from their responses is their ability to engage in interdisciplinary and cross-curricular activities that address complex real-world problems in contemporary societies (T1 and T7). The implementation of projects is seen by teachers as a fundamental element in promoting interdisciplinarity in schools.

> *"The school increasingly needs to be... it can't be just the classroom. In other words, in my understanding, maybe in the near future, the student enters the school and becomes a student at the school, and all of us teachers have to organize ourselves so that they are in the school space and learn in an interdisciplinary manner. That is, the problems we need to solve in our society regarding sustainability or whatever may be, they are complex*

problems. They can't be solved through physics, chemistry, or mathematics alone; they require an interdisciplinary approach. So, we need to work in a different way, breaking down the walls of the classroom, and students become students at the school." (T7)

"The school should close itself less and open itself more to the outside, and classes should be less confined and more cross-curricular, encompassing more disciplines and having more joint projects. Therefore, it doesn't make sense that it does not exist. I think it should be indispensable." (T1)

However, teachers are also aware of the challenges they face when introducing active methodologies into their classrooms. For instance, they point out that school culture itself often reinforces a certain way of working, making it difficult to promote alternative approaches among both students and teachers (T16). Additionally, challenges may arise from the classroom context and circumstances that hinder the implementation of broader activities such as projects (T15).

"Sometimes in the classroom, we can't carry out these types of projects, right? And we know that they are enriching for the students, and I think it's a valuable opportunity for us, right? [...] because we know that students develop other skills that are impossible to develop in the classroom. [...]. Last year, I couldn't do this experience [PjBL] when there were thirty students in the classroom, only twenty-seven, right? But now, with this small group of only twelve, we were able to do this project, right?" (T15)

"I think it's a bit difficult to involve and engage the students because they are very accustomed to traditional approaches, and they are also busy students, always with an extreme concern to prepare their school subjects, and sometimes they are not very available. It's not only the students; it's also the parents of the students and, of course, the teachers. But teachers, despite everything, despite being a class where making changes is difficult, I think they are the easiest to convince because they are people used to deal with the unexpected, with new situations." (T16)

In this regard, teachers perceive science clubs as tools to engage in activities that are often challenging to implement in a regular classroom setting (T7). In some cases, the science club has provided a common framework to integrate various small-scale projects and science-related activities initiated by teachers in the school (T2, T19).

"Of course, we always try to do projects that allow us to do different things with our students, but sometimes there is not enough time in the classroom. Therefore, I end up using the club's time as a complement. That is, my students are also in the club, most of them. It's almost inherent... and I complement the work in the classroom with the work in the club, and vice versa. That's the added value for me." (T7)

"Our application was to take all the science projects developed in the school and compete with all those projects in an agglutinating project that we called 'Desafíos'" (T2)

"We try to somehow articulate with existing projects in the school and provide support. Therefore, the science club aims to give relevance to all the existing projects in the school and help them articulate with each other and with various disciplines." (T19)

Aligned with their vision of teaching in schools, one aspect highly valued by teachers is the opportunity to design interdisciplinary projects that integrate different disciplines, in order to provide students with a holistic understanding of scientific knowledge (T18). The theme of interdisciplinary work consistently emerged in the interviews (e.g., T1, T2, T6, and T11). Additionally, teachers appreciate the opportunities created by these interdisciplinary projects to collaborate with colleagues from different fields of knowledge, allowing them to learn from one another (T7), gain better insight into their colleagues' expertise, and establish closer bonds (T14).

"Doing activities that can bring together various disciplines is difficult. We work in isolation in our daily lives, and even with these projects, we try to create a different idea because

today, society does not match compartmentalized knowledge. Everyone needs to have a little knowledge of various aspects to be able to control their specific area, right?" (T18)

"I think that a large part of my preparation as a teacher has come through this, through my involvement in projects with other teachers, even from other schools (...), my participation in these communities of practice." (T7)

"Firstly, I believe that it greatly helps the relationship within the school because what I say to the students also reflects on us. There is a close relationship between the teachers. [...] Having these colleagues collaborating helps us in other areas within the school. I quickly know that I have someone who is good at this or that, and I ask them for their help. And since I recently joined the school, if it weren't for the club, I wouldn't have discovered t my colleagues' skills so easily." (T14)

Throughout the interviews, the teachers provided various examples of projects undertaken with students within the science club context. These projects typically arise from different sources; however, three main origins can be identified.

(1) Teachers themselves decide to propose a project as a means to address specific curriculum content for a particular course (T1).

"A couple of years ago, we conducted a survey of the trees in the school park, and then we proposed it to the seventh-grade students. They saw the trees, where they came from, whether they were native or not. [...] This activity also emerged from the ideas of the seventh-class council. [...] Therefore, we have focused on this issue" (T1)

(2) Students who demonstrate curiosity and a desire to work on or delve deeper into a specific topic of interest (T2 and T7). In this sense, the club, through its projects, allows students to work according to their interests.

"So, if they want to learn how to make a bioplastic because they saw it on the Internet and we have the materials, then let's make a bioplastic. If they want to make conductive clay or a science challenge, they usually bring their own challenges because they watch YouTube or TikTok and come with their own interests. Through their own interests, they become involved. Therefore, we do not focus solely on teachers [proposals]. We also focused on the students' [suggestions]. What do they want to do? They actively participate in the activities." (T2)

"For example, they have a lot of interest in things related to astronomy at the moment, and maybe there is a competition in Portugal called CanSat. It exists in Portugal and in other countries. [In this competition] they [are challenged to] make a satellite of the size of a can and then we take temperature measurements, for example, using sensors. They are interested in doing something in the space field, so I engage in a brainstorm with them to explore what they want to do." (T7)

(3) The context in which projects may spontaneously emerge owing to diverse circumstances, such as commemorative dates of science landmarks or other events, providing the necessary context for project development (T1).

"Three years ago, we did a... It was a celebration of the first landing on the Moon. At that time, we organized an activity that involved the entire seventh grade. The kids created an exhibition and had a rocket competition that they launched at school. That was three years ago." (T1)

Furthermore, teachers view these projects as opportunities for students to engage in more comprehensive scientific research (T1, T7), resembling the actual practises employed in scientific fields, including aspects such as the communication of information and results through tools such as posters or videos (T2, T9, and T15). In these cases, as highlighted by T6, the benefits for students go beyond the specific content they learn but rather focus on the process of acquiring that knowledge, which is considered the most significant aspect.

"When it comes to secondary school, we try to implement a research project, a mini project, a small activity within the project, two years ago." (T1)

"At the beginning of 2018, we worked extensively on the topic of nutrition. Coincidentally, it was also the International Year of the Periodic Table. We conducted a research project focused on bread, in which the students incorporated different flours rich in various chemical elements, such as chromium and iron. They used alternative flours and conducted the study with the help of Science Alive. This collaboration allowed us to establish a partnership with an university, specifically a Faculty of Sciences, where the students had the opportunity to visit the laboratory, analyse the bread, and compare it with regular bread—experiences that we couldn't have provided at school." (T7)

"We also try to participate in other projects where students are required to work on more scientific tasks, such as creating posters, making videos, or giving presentations. It varies depending on the level of education we are working with." (T2)

"In the first cycle, throughout the school year, students work on projects and create posters to showcase the work they have been doing. They present and communicate their projects at the end of the school year during the Science Fair, where we gather all the projects completed by the students." (T9)

"For example, last year we worked on a project that connected science with art. We focused on cyanotype photography throughout the year, and the students created several cyanotype artworks. At the end of the year, we exhibited their works. It was displayed at the entrance of the school, and parents came to see it." (T15)

"No, I don't see a project as having specific contents. I believe that a project should be interdisciplinary, with the goal of exposing students to different areas and allowing them to learn in different ways. It's not like a traditional classroom setting; otherwise, it would just be a regular classroom. Instead, it's about engaging with the content, whether through emotions or cognitive aspects." (T6)

Conversely, in other cases, the final outcome of the project is not a presentation, poster, or video, but a tangible artefact that can be manipulated and utilised, as indicated by teachers T9, T15, T16, and T17. In the latter case, teacher T17 further noted that the artefacts constructed in club projects can also be employed in regular classroom settings to illustrate specific content.

"We don't just want the students to create a solar collector. No way. They must communicate all the steps involved in their research work, leading up to their proposed solar collector. All the solar collectors will be tested for their efficiency. Additionally, they will be required to create a poster where they report on all the steps and stages of their investigation in developing the solar collector." (T9)

"In our other workshops, we work on projects as well. For example, in the 'Science Splashes' workshop, during the last term, we worked on creating carts powered by elastic potential energy. The students used reusable materials to build the carts. Now, in this term, they are transitioning to carts powered by solar energy. They are beginning to think about the types of materials they need and what needs to be acquired. They are even looking for old carts from which they can remove the motors and wheels for reuse." (T15)

"Furthermore, the chemistry department will also collaborate with us by either hosting our students or working with us to create a prototype of a water treatment station. This way, the students can see and understand the processes involved in water treatment." (T16)

"For example, we can create an interdisciplinary project involving physics from the ninth grade. This involves engineering, technological education, design, and printing. We have the printers here [so we can print small 3D cars that use a balloon as a 'motor'] and we can then [use them to] study Newton's third law, which is about action and reaction, from the ninth-grade physics curriculum. This can be connected to different subjects. The objective is to develop activities that reinforce learning and that are not disconnected from the curriculum. When I'm talking about sound, for example, when I'm discussing sound, we have an ultrasonic sensor here [on the rover's head]. Its function is to measure

distance. These are things that I bring into the classroom. Sometimes, I bring these gadgets to the classroom when we're studying sound." (T17)

In some instances, these projects address current complex issues, such as sustainability, with microplastics being a recurring theme in several interviews (T1, T2, and T9). In other cases, projects developed within the club aimed to connect the school with the community, for example, by providing a service to the community (T19).

"Then, two years ago, we conducted an activity on microplastics. We performed statistical analysis of the quantity and chemical composition of plastics and their effects on living organisms. That was another project we worked on." (T1)

"In 2018 and 2019, we had a major project in partnership with the Faculty of Chemistry in Porto, focusing on microplastics. It was a well-structured project in which seventh-, eighth-, and ninth-grade students participated. Water samples were collected from beaches near their homes, analysed for microplastics, and observed under a microscope. It was a year-long project centered around microplastics, but we always try to involve all students in the school cluster." (T2)

"In the case of the subject I teach, CSAV (Science, Society, and Environment), one of the research topics is related to water, [namely] the presence of microplastics or water quality. Landscape laboratories conduct research in this area. So, what we have planned is to have the students monitor and observe the presence of microplastics in water and document it through photography." (T9)

"Many of the club projects are related to the daily life of the community... For example, a few years ago, we had a project in which we cleaned a small stream that ran near a school. It is often polluted by plastics and other debris. What did we do? We cleaned the river, and the project focused on the ecosystem and importance of cleaning rivers. It was a very interesting project, and the students actively participated in the cleanup." (T19)

"For instance, electronics. Students have a community support centre for repairing household appliances, computers, smartphones, and anything related to electronics. During this week and the next, they will be available at the local council office with specific hours for community assistance." (T19)

Ultimately, as reflected in the response of T16, teachers demonstrate a genuine interest in learning to work with these methodologies, to the extent that they actively seek specific training opportunities to expand their knowledge and incorporate these methodologies into their practises. Teachers like T7 acknowledge the indispensable role of training, since the project-based approach differs from usual classroom practises.

"Actually, in this second semester, or rather in the first semester of 2023, we are going to have a training session conducted by our partners from the University on active learning. In particular, the twelfth-grade teachers will try to apply the project-based methodology to involve more and more students... because it's challenging to work with project-based methodology, for example, right? Several other active methodologies have been proposed. But it's necessary to talk about how to teach or at least read, experiment, and apply it to our students, and that's what we're going to do." (T16)

"The role of the teacher, in the club, is that of a mediator, a privileged interlocutor, someone who has quicker access to objects of knowledge. But who doesn't possess knowledge about everything because we are working in unknown territory... It's a bit about deconstructing the traditional role of the teacher, right?... Not so much as a transmitter or someone who is there just to teach. In the club, I don't feel like I'm teaching. In the club, I feel like I'm creating opportunities, providing resources, and trying to facilitate their access to what they neede." (T7)

However, others, like T6, indicate that "*You do not learn this [conducting projects with the students] in university. You learn this day by day*", because, as T17 mentioned: "*There are things* *that can only be acquired through experience*" (T17). Therefore, they value the opportunity that the club provides to develop these projects with students and to learn along the way.

> *"It's not necessary to spend a semester learning this. You don't learn this at university. You learn this daily. [...] I don't think you can learn to do projects at university. You learn by doing. It's like that saying goes, 'Learn by doing. Find someone who is willing to teach and is truly willing to guide a new person. That's when a person learns."* (T6)

5. Discussion

Exploring the Potential of Active Methodologies in Science Clubs

The analysis of the interviews revealed that teachers who coordinate school science clubs are aware of the significant role that active methodologies can play in science education. In this regard, their perceptions of education in the 21st century stem from the premise that the traditional transmissive model of teaching should be drastically different, advocating for student-centred approaches and more frequent interdisciplinary project-based learning.

However, educators also recognise the difficulties and challenges associated with this transformation. Similar to findings in other studies [7,58], teachers acknowledged that the implementation of methodologies such as projects is constrained by school-related factors, including limited time, lack of suitable spaces, and insufficient financial resources. They are also aware that resistance to change may arise within the educational community, including students, parents, schools, and even some members of the teaching staff. Furthermore, they mentioned the lack of training as another challenge that needs to be addressed in order to achieve the proper integration of active methodologies.

In this context, teachers are acutely aware of the need for professional development to effectively employ these methodologies in their classrooms. They demonstrated a willingness to actively seek and engage in training activities that focus on practical applications involving both themselves and their students in project-based learning.

This is where the importance of science clubs lies, because they provide an environment conducive to tackling these projects. Considering the results of studies such as Martín-García et al. [59–61], it appears that clubs can help mitigate the resistance and issues often pointed out to the implementation of active methodologies in the classroom. Clubs, namely those working in partnership with external institutions, offer more time and resources to teachers, providing a safe space to carry out these activities with support from other organisations, serving as a platform for ongoing learning and development through experiential learning.

Thus, as highlighted in the preceding section, science clubs act as escape valves, enabling the implementation of activities or projects that are typically challenging to conduct in the classroom. Simultaneously, they serve as testing grounds where teachers can innovate and introduce new methodologies (T3), allowing them to experiment, practise, and familiarise themselves with these approaches in a more comfortable and less pressured environment.

> *"[...] we are trying different things and, therefore, we know that there are things that already work and maybe it gives us some confidence, more than trying it for the first time, because at the end of the day our experiences were in the club, isn't it?"* (T3)

Another crucial aspect for understanding why teachers find opportunities to develop projects in science clubs that they do not have in formal classes is funding. As highlighted by T10, many projects often cannot be realised because of a lack of funding or equipment. The integration of clubs into the Ciência Viva network addresses this issue by providing the necessary financial support demanded by teachers, as well as additional equipment and resources offered by the entities collaborating with the network and the clubs in each school (T9, T15). The possibility of accessing additional funding through the club significantly expands the possibilities and options available to educators.

> *"Many times, projects don't happen because there is no funding. So, the first step was to show colleagues the opportunity that existed when there was a budget. With the available*

funds, if possible, they can invite the speaker or organise the initiative. So, the club served as a framework for what already existed." (T10)

"Well, we have partners sometimes just for specific projects, right? We try to reconcile and find partnerships to provide us with new materials. [...] This year, for example, in the first semester, we had a partnership with Texas Instruments. They provided us with the materials and kits to create an automatic irrigation system, right? So, we do have partners sometimes just for specific projects, right? We try to reconcile and find partnerships to provide us with some materials that we don't have." (T15)

"So, we have several partnerships with the company that provided us with the aquariums" (T9)

One interesting aspect that stood out from the collected responses was that the teachers seemed to associate the idea of active methodologies with the implementation of projects. They did not mention other approaches such as problem-based learning, flipped classrooms, or design thinking. Previous studies [61] have highlighted that teachers coordinating science clubs value the opportunities they provide for the development of extensive and long-term activities and projects beyond the school curriculum.

Specifically, teachers believe that these types of projects offer a highly enriching experience for students, as they allow for interdisciplinary work across different areas of knowledge and the development of competencies and skills that would be challenging or nearly impossible to achieve solely in the classroom. This may explain why the teachers primarily focused their responses on this type of active methodology.

These results reflect how teachers value interdisciplinary work and consider it one of the major advantages of science clubs, aligning with their vision of how classroom work should be conducted. In this sense, club projects also contribute to students' learning about wicked problems [62] and socioscientific issues [63], the complex challenges that contemporary societies face at the social and scientific levels. These problems can only be addressed from a holistic and integrated perspective, considering them from different viewpoints and with the knowledge of various areas of expertise.

However, the development of projects within clubs also appeared to have beneficial effects on teachers. The fact that the teacher's role in these activities differs from what they typically perform in the classroom makes the club a valuable learning tool. Moreover, it provides realistic and practical training that takes place within the work environment [64].

Being in charge of a club requires teachers to step out of their comfort zones and engage in tasks that are not typically performed in science classrooms. Teachers such as T7 and T15 acknowledge that clubs promote professional development by encouraging teachers to seek ways to expand their knowledge to bring new projects and topics to the club. It seems that in order to work on a specific theme in the club, teachers have had to research and learn about that topic and how to approach it. Evolution at the professional level implies not only self-directed and autonomous learning [65]; teachers also mentioned engaging in professional training courses to seek support, as shown in the extract from T16 at the beginning of the previous section:

"For example, there are certain activities where I want to participate with the students, like the ones I mentioned earlier. If they really want to participate in CanSat this year, as a teacher, I am obliged to guide them to undergo training, which also contributes to my professional development. It's a process of self-learning where, as I mentioned earlier, I have the ability to work with the students as a facilitator of their learning." (T7)

This personal development is expressed with positive feelings towards teaching, as stated by teacher T7: "*deep down, I started to adhere to this kind [of projects]... to motivate myself because, sometimes, the work of the classroom alone is a little routine, demotivating*".

Nevertheless, the results described in the previous section indicate that teachers consider different motivations when planning and developing projects in science clubs. For example, in some cases, projects are designed to address a specific part of the curriculum during a particular academic year. In other cases, the choice of theme stems directly from students' interests, providing them with the opportunity to learn and delve deeper into topics that fascinate them.

The promotion of scientific culture and the connection between scientific development and social well-being appear to be additional motivations for initiating projects in science clubs. Some teachers emphasise the development of specific projects to commemorate notable events (such as the Moon landing) or significant dates in the history of scientific advancement. Lastly, the possibility of opening the school to the community and engaging in social services is also present in some responses, particularly those provided by T19, aligning with the goals set for the creation of the Rede de Clubes Ciência Viva [66].

However, there is an aspect of the results that requires further discussion. Teachers' responses did not clearly indicate the extent to which the described activities fit within the parameters or basic characteristics of PjBL. Specifically, the teachers refer to the "implementation of projects", but there may be doubts as to whether the way these projects are approached aligns with the described framework of PjBL. For instance, when examining the different definitions of PjBL proposed by various authors [11,13], it becomes evident that a fundamental element is absent from the interviews: the guiding question that drives the project.

Indeed, the transcripts of the interviews did not show teachers referring to a question that structured the project or presented a problem that required a solution. It is true that in specific cases, such as T9 (efficient solar collector) or T7 (CanSat—building a satellite in a can), the question or problem can be inferred from the responses, but it is not explicitly stated. Based on the collected testimonies, it seems that the projects are driven more by the chosen theme or the content to be promoted, rather than by a guiding question or problem that needs to be addressed.

Moreover, another element of these definitions that did not fully emerge from the respondents' answers was the notion of artefacts. Some teachers' responses (for example, T2, T9, and T15) suggest that they conceive of the project's culmination as the presentation of a poster or video documenting its development, which indicates that PjBL demands the creation of an artefact that serves as the final product of the learning process. This was evident in specific cases (e.g., T9, T7, and T17). Therefore, it is uncertain whether the interviewed teachers truly comprehended the significance and implications of PjBL. This highlights the need to emphasise teacher training as a driving force for promoting the incorporation of active methodologies in the classroom.

In conclusion, the presented results allow us to conclude that while some of the surveyed teachers may not have a clear understanding of what Project-Based Learning entails as an active methodology, they recognise that school science clubs are a good option for the development of extensive and enriching projects for students. These clubs are not subject to the same limitations as formal education, thus providing better characteristics and conditions for the implementation of these types of activities.

6. Conclusions

This study focuses on the voluntary adoption of active instructional strategies by science teachers within the context of science clubs. The findings reveal that participants in this study are aware of the need and importance of promoting educational changes towards a student-centred approach in which students play a more active role.

Furthermore, it has been observed that teachers often associate active methodologies with project-based learning (PjBL). However, it is important to note that the teachers' interpretation of "carrying out projects" does not necessarily encompass all the characteristics described in the literature for PjBL.

Therefore, while teachers acknowledge the need for practical, real-world project-based learning experiences for students to acquire project skills, this study emphasises the importance of creating academically oriented training programmes for teachers. These programmes should provide a solid conceptual foundation for understanding the principles of PjBL, including the essential features of instructional sequences, the necessary conditions, and effective implementation strategies. Such programmes would enhance teachers' understanding of what PjBL entails and bridge the gap between teachers' perceptions and theoretical conceptualisations.

Moreover, in line with teacher insights, the results highlight the need for more opportunities and situations that allow teachers to practise and implement active teaching and learning strategies before introducing them into conventional classrooms. Science clubs, as examples of long-term scientific activities, have been identified as suitable environments for this purpose. The conditions provided by science clubs, including time, resources, funding, and collaboration possibilities with peers and professionals from different fields (university researchers and other research centres), allow projects to reach a new dimension and overcome the limitations and constraints often encountered in traditional school settings.

The relaxed and informal atmosphere, the student–teacher relationship, the trust built between teachers and students, fluid communication, and the distinct role of teachers in science clubs all contribute to overcoming initial hesitations from both teachers and students, facilitating the successful incorporation of PjBL in science clubs.

Finally, teachers express various reasons supporting the importance of carrying out projects in science clubs and highlight the value they place on the opportunities created by these clubs. Although they recognise the additional effort and work involved, they experience personal satisfaction in making a positive and beneficial impact on their students' development. Projects enable students to acquire knowledge and develop skills and attitudes that may not be fully attainable in a regular classroom setting. This personal satisfaction becomes the driving force that motivates teachers to continue improving and striving for science education that aligns with their ideals and convictions.

This study provides a glimpse into the adoption of active methodologies by science teachers in science clubs. The results emphasise the importance of providing science teachers with professional development opportunities in active methodologies and combining academically oriented training programmes with opportunities for practise and experimentation in real-world situations. Within this framework, science clubs are identified as key facilitators for the successful implementation of PjBL because of their characteristics and non-formal nature.

In conclusion, this study has educational implications for the implementation of PjBL and highlights the importance of further exploring and promoting active instructional approaches such as PjBL in order to enhance science learning and to foster student engagement in their own learning process. From the perspective of science education research, this work provides a solid foundation for future research on the design and evaluation of educational programmes that integrate the PjBL approach and the role of non-formal contexts in improving science education. However, further investigation is essential to promote greater integration and to better understand how to incorporate these contexts into formal teaching.

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