Research article

Interdisciplinary teaching practices in STEAM education in Brazil

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Abstract

This study explored primary school teachers' self-efficacy beliefs about interdisciplinary teaching practices related to science, technology, engineering, arts and mathematics (STEAM) education and project-based learning to understand teacher perceptions and practices and to recommend some teacher training according to the national curricular standards in Brazil. Qualitative data were gathered using semi-structured interviews carried out with in-service teachers, which were supplemented by a questionnaire featuring both closed-ended and open-ended questions. The data were subsequently subjected to quantitative analysis. The findings reveal that while most teachers are familiar with and incorporate project-based learning into their pedagogical approaches, their awareness of and training in STEAM education are limited. Nevertheless, teachers perceived themselves as being very competent across most STEAM domains, including interdisciplinary curricular integration and projects. Chemistry, physics and arts are exceptions, with lower levels of teacher self-efficacy when compared to the other disciplines. This article examines the implications of these findings for pedagogical practices and teacher training in Brazil, while addressing what are teachers'

current perceptions of STEAM practices, encompassing project-based learning and interdisciplinarity. It identifies the training requirements necessary to enhance their confidence in teaching science, while integrating arts-related subjects.

Keywords STEAM education; interdisciplinary teaching; project-based learning; teacher self-efficacy; teacher training; primary school teachers

Introduction

STEAM education in Brazil

In Brazil, as in many other countries, primary education is entrusted to a teacher who possesses a broad range of knowledge and competencies. Typically, this generalist teacher is responsible for teaching a broad spectrum of subjects, encompassing the natural sciences, the native language (Portuguese), mathematics, history and geography.

Notwithstanding the existence of a specialist teacher in the school, the areas of technology, English language, physical education and the arts (music, visual arts, drama and dance) are also under the responsibility of the generalist teacher, even if they are worked on in an interdisciplinary way, within projects, or transversally, within other themes.

The requirement for teaching in the initial years of basic education (namely, pre-kindergarten to fifth grade) is a degree in pedagogy, and teachers are not legally required to have a postgraduate degree, despite the ample supply of such degrees in the country. In the initial phase of teacher training, the National Curricular Standards for the Graduation Course in Pedagogy state that, upon graduation, the student teacher can teach, among other subjects, the arts in an interdisciplinary way and adequately for the different phases of human development (Brasil Ministério da Educação, 2006).

Interdisciplinary teaching can occur through the STEAM pedagogical approach and practice, which aims to empower students equally within the areas of science, technology, engineering, arts and mathematics (STEAM), using project-based learning as methodology, as well as solving real-world problems through creative processes (Khine and Areepattamannil, 2019; Perignat and Katz-Buonincontro, 2019). When worked within an artistic and collaborative framework, project-based learning offers resources for autonomous, effective and permanent learning (Salido-López, 2021), on the basis of experience (Dewey, 2010). Scholars have argued for the use of project-based learning methodology in STEAM education, as it gives a more active role to students and promotes the development of skills adapted for the twenty-first century (Bacich and Holanda, 2020).

Integrating the arts (A) into science, technology, engineering and mathematics (STEM) education (often referred to as STEAM education) can lead to a more comprehensive and holistic learning experience for students, directing them towards creative processes (Perignat and Katz-Buonincontro, 2019) and helping teachers to create a more engaging and relevant curriculum. As regards competencies, STEAM education meets international standards (OECD, 2016; UNESCO, 2016), which presupposes barriers' breakdown between disciplines, promoting interdisciplinarity, in addition to contributing to the United Nations Sustainable Development Goals of Agenda 2030 (Tomé, 2021), and to some of the Brazilian objectives for education proposed in the Common National Curriculum Base (CNCB). This is a national reference for the formulation of curricula and pedagogical proposals of school institutions at the federal, state and municipal levels, referring to teacher training, assessment, the development of educational content and the criteria for the provision of adequate infrastructure for the full development of education (Brasil Ministério da Educação, 2018).

Despite not directly mentioning STEAM education, the CNCB uses guidelines organised by competencies and skills, a fact that, in the view of Bacich and Holanda (2020), is aligned with STEAM discourses on twenty-first-century competencies. In addition, some general competencies established in the guidelines are related to the principles of the STEAM approach, such as the exercise of intellectual curiosity using the scientific approach, including research, reflection, critical analysis and creativity to solve problems and create solutions based on the knowledge of different areas. The contemporary

cross-cutting themes of the CNCB as proposals for implementation practices also suggest working through projects, which may be interdisciplinary or transdisciplinary (Brasil Ministério da Educação, 2019).

Notwithstanding the relevance and timeliness in the subject of STEAM education, which has sparked growing interest in research conducted in other countries (Garza and Travis, 2019; Khine and Areepattamannil, 2019; Marín-Marín et al., 2021; Martinez, 2017; Perignat and Katz-Buonincontro, 2019; Tomé, 2021; Turhal, 2020; Lederman et al., 2023), a literature review highlights that efforts for STEM education in South America seem to be in their very early stages in some interdisciplinary programmes (Johnson and Czerniak, 2023) and that the few existing practices in Brazil are aligned to project-based learning, with emphasis on the discipline of science, and are generally implemented in secondary education, in the south-eastern and southern regions of the country (Maia et al., 2021). The results of a systematic literature review show that although teachers value STEM education, they report several challenges of a curricular and pedagogical nature (Margot and Kettler, 2019), as well as concerns related to lack of training.

Teacher self-efficacy

Self-efficacy is a psychological construct that refers to an individual's belief about their ability to complete a particular task or their belief that they can take the necessary actions to produce specific performance achievements (Bandura, 1994). In the educational field, teacher self-efficacy includes the following dimensions: instructional strategies, classroom management and student engagement (Klassen and Chiu, 2010), referring to the accomplishment of classroom tasks (Lazarides et al., 2020), or even to the 'teacher's belief in his/her ability to generate a change in student learning outcomes' (Garvis and Pendergast, 2010: 7), because 'to be successful, the teacher must have both expectations high (of effectiveness and of results)' (Castro Silva and Silva, 2015: 91).

Teachers' self-efficacy influences their teaching behaviours as well as their students' motivation and performance (Tschannen-Moran and Hoy, 2001), and teachers who possess low self-efficacy experience greater difficulties in teaching, higher levels of work-related stress and lower levels of job satisfaction (Klassen and Chiu, 2010).

The current study

This study investigated primary school teachers' self-efficacy beliefs about interdisciplinary teaching practices within the realm of STEAM education and project-based learning. Additionally, it considered their perspectives on interdisciplinarity of pedagogical practices, the initial and in-service training of Brazilian teachers and their insights into the themes explored in this research.

As an exploratory study, its primary objective was to gain an understanding of the salient issues perceived by teachers within the Brazilian teaching context. It also aimed to establish correlations between teachers' identified needs and their potential contributions to education. Consequently, it provided a compass for future research directions and proposed strategies for enhancing teachers' professional development in these domains.

Despite the study's limited sample size, it offers valuable contributions, particularly in the qualitative results and discussions. These findings have the potential to inspire other educators and individuals interested in project-based learning, interdisciplinarity – both emphasised in Brazilian educational documents – and the STEAM approach.

Method

Participants and data collection procedures

In this research, 15 Brazilian teachers were interviewed. They worked in primary education (early years of basic education), in public (*n* = 9) and private (*n* = 6) schools, all located in the state of São Paulo, Brazil. With an average age of 41 years and an average of 13 years of teaching experience, most of the interviewees had a degree in pedagogy (*n* = 13), besides other training and postgraduate qualifications. Participants were 10 generalist teachers (first to fifth grade), 1 English-language teacher, 1 visual arts teacher and 3 auxiliary teachers. The auxiliary teachers had already worked as early years' teachers. The generalist teachers are responsible for a classroom and teach Portuguese language, mathematics,

natural sciences, history and geography. The three teaching assistants answered the interview questions based on their previous experiences as generalist teachers, with an average of 16 years of practice.

The interviews were conducted and recorded through a videoconference tool (Zoom), between October and November 2022. A semi-structured script was adapted from an online instrument disseminated among European teachers within the ProSTEAM Erasmus[+] project (https://www.pro-steam. eu/). The script consisted of 18 closed-ended and open-ended questions, including questions about teacher self-efficacy in STEAM education, project-based learning, interdisciplinarity and art integrated into curricula, as well as about teacher training. Open-ended questions about teacher training, both initial and in-service, and the opportunity for the interviewees to comment as much as they wanted on all the questions (justifications, context, reflections) were also added to the interview script.

Data analysis

The interviews underwent comprehensive transcription and analysis. The open-ended responses and supplementary questions were subjected to qualitative analysis through content analysis techniques (Bogdan and Biklen, 1994). The analytical process unfolded in distinct phases, as outlined by Bardin (2009). In the initial phase, we organised and prepared the transcribed material for subsequent analysis.

The second phase involved a systematic exploration of the material through coding and categorisation, consistent with Bardin's (2009) approach. We extracted recurring and salient responses aligned with the study's objectives, which primarily revolved around the observation and description of teachers' perceptions regarding STEAM, project-based learning and interdisciplinarity. Moreover, with regard to their training experiences and intentions, we meticulously gathered, transcribed and summarised responses to identify prevalent themes.

In the third phase, we delved into the interpretation and conducted critical analyses of these findings. This process involved relating the outcomes to the previously presented theoretical frameworks, such as teacher self-efficacy. Given the study's limited sample size, we opted not to employ content analysis software.

Responses to closed-ended questions were systematically saved in an Excel spreadsheet, coded and subjected to analysis using statistical software (SPSS version 28). Each question was associated with a specific category, labelled C1 to C18, and responses were coded based on their content.

For binary questions, responses were coded with 'yes' as 1 and 'no' as 0. Questions about teacher self-efficacy allowed for multiple response options, 'high' (3), 'medium' (2) and 'low' (1), often accompanied by supplementary open-ended comments.

For example, for Question 15, 'How confident are you in integrating concepts from different disciplines into your teaching practices?', the category assigned to this question was C15, and codes were 'high' (3), 'medium' (2) and 'low' (1), supplemented by explanatory comments.

Subsequently, all coded responses to closed-ended questions were introduced into the statistical software SPSS version 28 for analysis, including the use of the $\chi2$ (chi-square) association test. The goal was to obtain results about relevant associations. We tested all the independent variables, and only 12 analyses revealed a relevant significance level, that is, $p \leq 0.05$. The variables that showed a level of significance were the type of school (public or private) and the teachers' training level.

The age and length of teaching service of the interviewees, as well as the characteristics of the classes with which they are involved, did not exhibit statistical significance in the data analysis. All the findings from the analyses will be shown and discussed further.

Ethics

All participants were informed about data anonymity and confidentiality. They agreed to participate freely and voluntarily in the research, knowing that their names and workplace would not be disclosed, and that they could contact the researcher at any time during the research and in the future, including for access to the results. The interviewees were asked about their gender identification for referencing during the interview and data processing, and the research objectives were made clear to them.

Findings

Answering the first research question, 'What are Brazilian teachers' current perceptions of STEAM practices, including project-based learning and interdisciplinarity?', none of the 15 interviewees said that they knew about, used or had even received training in the STEAM educational approach; they generally replied, 'I have never heard of it.' Regarding project-based learning, or project-based pedagogy, as it is also known in Brazil, 13 interviewees stated that they were familiar with it and used it in their teaching practices, and 14 said that they knew about it and worked at some level with interdisciplinarity.

The interviewees self-assessed their confidence to teach in all areas of knowledge addressed by STEAM education. Responses included information on levels of self-efficacy (low, medium or high), as well as open-ended and additional comments. Teachers rated their teaching self-efficacy as high for all knowledge areas addressed – mathematics, biology, arts (including music education) and technology – except for chemistry and physics, with a tie in chemistry for high and medium teacher self-efficacy ratings, and a majority of medium ratings in physics. The area with the highest level of confidence to teach was mathematics, with $n = 10$ for high teacher self-efficacy; it was the only knowledge area with $n = 0$ for low teacher self-efficacy.

In terms of knowledge area integration, the findings indicate a notable level of teacher self-efficacy. The evaluation encompassed various aspects, such as integrating natural sciences with arts, incorporating music into the daily curriculum, introducing artistic expressions, implementing STEAM integration (involving multiple knowledge areas) and boosting the confidence to undertake interdisciplinary projects. The integration of diverse areas to solve problems or explain real-world phenomena, which we referred to as STEAM integration, resulted in the highest teacher self-efficacy ($n = 12$). Following closely was a strong confidence level in conducting interdisciplinary projects ($n = 11$). In contrast, music education emerged as the knowledge area with the highest number of responses indicating a low level of teacher self-efficacy ($n = 5$). When it came to questions regarding integrations, both musical integration and integration of artistic expressions had the highest frequency of responses indicating a low teacher self-efficacy ($n = 3$ each).

Most of the interviewed teachers ($n = 12$) evaluated that their initial training did not prepare them to teach or integrate music in the classroom context, nor did it prepare them to teach arts in an interdisciplinary manner and in ways appropriate to the different stages of human development ($n = 13$).

Regarding the positive and negative aspects of STEAM integration, the most frequent responses were: 'it is valuable for learning', it is 'laborious' and 'the teacher lacks time to carry [it] out'. Regarding the positive and negative aspects of carrying out interdisciplinary projects with students, the highest frequency of responses showed that student participation is a positive point for project-based learning and that this approach is a facilitator of learning. However, on the negative side, there is a lack of time, resources and training to carry out interdisciplinary projects with confidence and effectiveness.

When asked about the type of teacher training that Brazilian teachers need to raise their level of confidence when working with STEAM education, project-based learning and interdisciplinarity, among several responses, the most frequent category was 'theories and practices', followed by training in 'specific disciplines or areas of knowledge'. This addresses the second research question, 'What kind of training do Brazilian teachers need to develop their confidence in teaching science, in meaningful combinations with arts-related subjects?'

To complement the data analysis of the open-ended questions, data analyses of the closed-ended questions were performed using the statistical program SPSS version 28, through the $\chi2$ (chi-square) association test ($n = 15$). In this way, we were able to include more data in the analysis and obtain a statistical overview, even though the sample was small. We considered only 12 analyses that obtained a relevant significance level ($p \leq 0.05$). Category 1 (STEAM) was excluded from the analysis, since the variable presented less than two levels, because all the interviewees answered that they do not know about and/or do not work with STEAM education.

The independent variables that showed a level of significance were the type of school (public or private) and the teachers' training level. These were important data, and they will be discussed in more detail later on. The analysis revealed an association between private school teachers and their self-perception of being more effective in teaching physics ($\chi2 = 6.11$; $p = 0.047$), and technology ($\chi2 = 6.67$; $p = 0.036$), as compared to their counterparts in public schools. Additionally, teachers holding postgraduate degrees (degree and specialisation) displayed higher levels of knowledge and utilisation of project-based learning ($\chi2 = 15.0$; $p = 0.036$), and interdisciplinarity ($\chi2 = 15.0$; $p = 0.036$) compared

to those without such qualifications. In summary, the findings indicate a positive association between postgraduate training and proficiency in implementing project-based learning, as well as a positive association between this type of training and interdisciplinary practices.

The age and length of teaching service of the interviewees, as well as the characteristics of the classes with which they are involved, did not exhibit statistical significance in the data analysis.

Discussion

In this section, we discuss the results, showing how they can answer the research questions. Regarding the question of Brazilian teachers' current perceptions of STEAM practices, including project-based learning and interdisciplinarity, in the introductory questions of the interview, some interviewees showed curiosity, especially about STEAM, since none of them had heard about this approach. After a brief explanation from the researcher, some took notes; others commented that it was a very interesting approach.

Regarding project-based learning and interdisciplinarity, although most stated that they are familiar with it and practice it at some level of education, many stated that they do not have enough training, both theoretical and practical, and that they would like to know more about it. This may demonstrate that STEAM education is in its early stages in Brazil (Johnson and Czerniak, 2023), but despite this, project-based learning and interdisciplinarity are key concepts in contemporary education, which align with the CNCB.

Given that STEAM is not formally incorporated into the official documents of basic education in Brazil, this study embarked on an exploration of fundamental or burgeoning aspects of STEAM initiatives. These included an investigation into methodologies such as project-based learning, which is widely acknowledged as the most accepted methodology within this approach.

Furthermore, we examined the training requirements identified and aligned with official Brazilian directives. This alignment has significant implications for educational policies, fostering a nuanced understanding of how STEAM can be integrated into the national educational landscape.

In the following sections, we discuss the main topics of this research, aligned with the outcomes that have emerged from our research. These discussions are harmonised with our research inquiries and substantiated by the pertinent literature in the field.

Teacher self-efficacy about STEAM

The interviews explored specific questions about teacher self-efficacy, and the interviewees were asked about their level of confidence in different teaching areas, and in the integration between them, which helped us to understand their perceptions. This level of confidence refers to teaching concepts from these subjects as found in the curriculum and/or related to everyday life contexts, and which were subsequently analysed as efficacy and outcome expectations, according to the construct of self-efficacy.

The teaching confidence assessed involves:

- providing effective teaching across the school curriculum
- explaining difficult content in a way that students understand
- suggesting appropriate examples when students are having difficulty understanding
- teaching in a way such that students remember important information
- applying changes in the school curriculum to teaching practice
- helping students to focus on learning tasks and avoid distractions
- managing inappropriate behaviour in class
- encouraging students to take responsibility for their behaviour
- addressing the diverse learning needs of students in the classroom.

The term *teaching concepts* implied in all the teacher self-efficacy questions caused some mistrust or disagreement among some interviewees, who claimed that they had no obligation to teach chemistry, physics or arts concepts, even though they are always approached in an integrated manner. We should clarify that the term does not imply traditional teaching; on the contrary, in the context of the interviews, teaching such concepts includes interdisciplinarity of the areas through projects, or the integration of subjects and areas of knowledge.

However, it is interesting to note that such a question arises precisely in the areas that had the lowest frequency of responses for high teacher self-efficacy (chemistry and physics), and the highest frequency of responses for low teacher self-efficacy (music education and arts integration). Teachers who possess low music teacher self-efficacy are less likely to use music in teaching (Weiss, 2019). As mentioned above, teachers with low self-efficacy also experience greater difficulties in teaching, higher levels of work-related stress and lower levels of job satisfaction (Klassen and Chiu, 2010).

Regarding science teaching, where chemistry and physics are included, teachers tend to feel that it is not a creative area, that it is too objective and that they do not have a background in scientific, inquiry-driven thinking, which makes them avoid science teaching with their students (Akerson and Bartels, 2023).

In general, teachers rated their teacher self-efficacy as high for all the knowledge areas addressed (mathematics, biology, arts, music education and technology), except for chemistry and physics, with a tie in chemistry for high and medium teacher self-efficacy assessments, and a majority of medium ratings in physics.

The subjects of biology, chemistry and physics were considered within natural sciences, as provided for in the curriculum for this stage. The arts curricular component, meanwhile, is usually taught by a specialist teacher, but, despite this, generalist teachers are expected to integrate the arts in their teaching in an interdisciplinary way. Similarly, technology is not a curriculum unit, but it permeates all areas of knowledge. Specific questions were also asked about music education within the arts, which is also thought of in an interdisciplinary way.

Engineering was not included in the survey instrument, despite it being a knowledge area of STEAM education, because it does not have its own contents for the age group of primary education. It can be assessed in the context of projects, being integrated in all areas, with a focus on problem-solving and the design of creative solutions (Bacich and Holanda, 2020).

The knowledge area that had the most responses for high teacher self-efficacy was mathematics (n = 10), with no responses for low teacher self-efficacy. We believe that this is due to the importance given to in-service professional training with a focus on written language literacy and mathematics in the first years of education, especially in the post-Covid-19 pandemic phase. As Teacher 9 commented: 'with this pandemic time, the school is quite focused on reading–writing and literacy even. With all this delay that we ended up having, it was very focused on this issue of literacy, because that is where the biggest gap is.'

It is interesting to note that the highest frequency of high teacher self-efficacy responses for integrations was in the STEAM integration category (n = 12), even though the interviewees had never heard about the approach, which may demonstrate an organic path for the integration of knowledge areas, even if it is not exactly within the STEAM approach.

The second highest level of confidence in the integration category is related to carrying out interdisciplinary projects (n = 11), with project-based learning being the most accepted methodology among STEAM authors and researchers (Bacich and Holanda, 2020). Involving goals of STEAM, project-based learning is a transdisciplinary teaching approach that has demonstrated learning, increased collaborative skills, critical thinking and problem-solving skills (Herro and Quigley, 2017).

General teacher self-efficacy about arts integration

The area of knowledge that had the most responses for low teacher self-efficacy was music education (n = 5). In the questions that involved integration, the areas of music integration and integration of artistic expressions also had the highest number of answers for low teacher self-efficacy (n = 3). Furthermore, most of the interviewed teachers (n = 12) evaluated that their initial training did not prepare them to teach or integrate music in the classroom, nor did it prepare them to teach arts interdisciplinarily and in ways appropriate to the different stages of human development (n = 13), according to the Brazilian National Curriculum Guidelines (Brasil Ministério da Educação, 2006).

Beginning teachers develop beliefs about their performance in arts education that shape their future beliefs about teaching arts in the first years of education (Garvis et al., 2011; Relvas, 2016). The literature focusing on self-efficacy of arts teaching by the generalist teacher has shown that education students (Hallam et al., 2009; Russell-Bowie, 2009) and generalist teachers do not feel confident working with the arts in the classroom, and already develop low self-efficacy beliefs about teaching arts, and music more particularly, in the first years of education (Garvis et al., 2011), whether it be through an arts

or interdisciplinary proposal (Biasutti et al., 2015; Garvis et al., 2011; Hallam et al., 2009; Henriques, 2011; Rosa-Napal et al., 2020; Russell-Bowie, 2009; Welch, 2020).

This lack of confidence originates from the limited preparation for such a task in their initial (Kenny et al., 2015; Welch, 2020) and in-service training, and the lack of support in the classroom (Garvis and Pendergast, 2010), leading teachers to consider that they do not have enough theoretical pedagogical knowledge, which translates into low teacher self-efficacy.

According to Welch (2020), such results are evidenced in several countries, including England, Australia, Ireland, Scotland, Brazil and Portugal. They are also evidenced in comparative studies between several countries, including Australia, the USA, Namibia, South Africa and Ireland (Russell-Bowie, 2009).

In Brazil, this converges with the results of our research, which showed increased low teacher self-efficacy beliefs about music education and arts integration compared to other areas of knowledge and curricular integration. This is further reinforced by the fact that most teachers interviewed evaluated that their initial training did not prepare them to teach or integrate music in the classroom, nor did it prepare them to teach the arts in an interdisciplinary manner that is appropriate to the different stages of human development.

Current research is focused on the topics of creativity and arts, as they are likely to be the new trends in the STEAM education field of study (Marín-Marín et al., 2021), which includes the arts as a knowledge area of an integrative and holistic education, as proposed by Yakman (2008).

Recognising that in-service training can be an answer to enhance the teacher self-efficacy in arts education (and in other areas), studies have been conducted on intensive training programmes, with national (Iaochite et al., 2016) and international (Biasutti et al., 2015; Hauge et al., 2016) experience.

Teacher self-efficacy and professional development

Teacher self-efficacy and professional development are important, impacting teaching performance and student learning (Tschannen-Moran and Hoy, 2001), and this is addressed by the second research question, which concerns what kind of training teachers need in order to develop their confidence in teaching science, in meaningful combinations with arts-related subjects in an interdisciplinary way.

Several interviewees talked about the relationship between the in-service training received during their professional development and their confidence in teaching, that is, teaching self-efficacy. For example, when asked about work with interdisciplinarity, Teacher 9 let out her frustration: 'that's why today I do not feel competent for much, because I simply do not know', and that 'it [interdisciplinarity] is much talked about, but it does not happen in the classroom, it's only to fulfil a speaking role'.

This response reflects a chasm from the Brazilian CNCB, which proposes learning based on twenty-first-century skills and abilities, highlighting the importance of interdisciplinarity and project-based learning. As mentioned above, despite not making direct mention of STEAM, the CNCB is aligned with STEAM discourses on twenty-first-century competencies (Bacich and Holanda, 2020). It may show that in-service education is not aligned with teachers' needs, as teachers perceive themselves as not so competent for this type of teaching and learning. About this, the literature indicates a body of main characteristics for high-quality professional development activities, including long duration, collective participation, active learning and coherence (Gümüş and Bellibaş, 2023).

Margot and Kettler (2019) found that the support needed for teachers to implement STEM should include effective professional development. Formal teacher training was also positively associated with teacher self-efficacy for instruction, while positive informal classroom experiences were positively related to teacher self-efficacy in student engagement (Fackler and Malmberg, 2016).

In their study of 14 OECD countries, Fackler and Malmberg (2016) argued that, although there was no significant relationship between self-efficacy and teachers' level of formal education, teachers with higher levels of education (specialisations, master's or doctoral degrees) show higher perceptions of teacher self-efficacy. This also happened in our study, the teachers with postgraduate degrees (specialisation, master's or doctoral degrees) showed higher levels of teacher self-efficacy about the knowledge and use of project-based learning and interdisciplinarity in their practices.

According to Gümüş and Bellibaş's (2023) survey of 32 countries, Brazil was the only country in which a higher educational level was positively correlated with teacher self-efficacy. Despite the small sample size, our study confirms this.

Teachers' views on STEAM education, interdisciplinary projects and the integrated curriculum

Teachers were also asked what they considered to be the pros and cons of STEAM integration (defined as the integration of disciplines/areas of knowledge) and pedagogical work with interdisciplinary projects. Their answers showed that most considered STEAM integration positively as being 'valuable for learning' and negatively as being 'laborious', and that there is a 'lack of time to carry out and/or plan'.

Regarding working with projects, most of the interviewees evaluated that student engagement is an advantage, along with the fact that it is a 'facilitator of learning'. On the cons, they assessed that there is a lack of time, training and resources to be able to truly carry out project-based learning autonomously and effectively. Among other aspects, they named the need for teachers' predisposition to seek training and means to work with projects. Besides there is a conceptual problem about what project-based learning in fact would be, which could hinder a common sense understanding of the subject. Project work should consider the strategy of differentiation of content, learning, activities and time, and it should be centred on the students' work (Grave-Resendes and Soares, 2002).

Corroborating these results, studies conducted worldwide on the views of teachers about curriculum integration (fundamental in STEAM and project-based learning) suggest that teachers generally have positive views on the subject, but perceive barriers regarding the adoption of the pedagogical practice (Johnson and Czerniak, 2023).

Demonstrating the difference between the expectation of effectiveness and results, Teacher 1 said that they felt that their teacher self-efficacy was high about the management of content and teaching in general. However, this confidence was diminished by the inappropriate behaviour of students and family members, as well as by the devaluation of the teaching profession. Teacher 1 also pointed out that children returned from the isolation period of the Covid-19 pandemic with more infantilised behaviours, as there was a deficit in social interaction between them, and some values were 'damaged'.

Several interviewees also linked confidence in teaching with appropriate planning time; as Teacher 8 commented: 'If I had time to sit down, plan, I would feel more confident, but the problem is that it doesn't always happen.' Teacher 8 also said that there is no predisposition of many teachers to do something different or to seek something new, such as interdisciplinarity or project work, which would be inherent to the generalist teacher, and that 'it even seems like a belief [of the teachers] that the human being is not capable of learning in a more holistic, more global way'.

The professional development of Brazilian teachers

When asked about the type of in-service training that Brazilian teachers need to raise their level of confidence in working with STEAM education, project-based learning and interdisciplinarity, among several responses, the most frequent was training in 'theories and practices', followed by training in 'specific disciplines or areas of knowledge'.

The literature highlights a recognised need for intervention training that are closely aligned with teachers' school contexts, including mentoring and coaching (Gümüş and Bellibaş, 2023). Moreover, it has been demonstrated that teachers' disciplinary content knowledge can hinder integration across the curriculum (Johnson and Czerniak, 2023).

The interviewees also criticised the in-service training received in both public and private education as being incompatible with their needs as in-service teachers. The training is purely theoretical, abstract and distant from their reality, or even provides only indications for action by the management, like a prescription or recipe. It is often not coherent, has no theoretical framework and does not lead to a change of reality in the classroom, since teachers do not feel confident about or prepared for change.

Some interviewees also pointed out the need to have more knowledge in the arts area, as well as the need to bring the teacher closer to the Brazilian public university, both in research and in postgraduate studies. There is a requirement for, or added value provided by, in-service training being taught by researchers and specialists in these areas, and not by the management team or training centres, which is what happens in Brazil most of the times.

Public school versus private school in Brazil

Private school teachers provided responses that exceeded what was expected in terms of their teacher self-efficacy regarding physics and technology compared to public school teachers. Despite public school teachers demonstrating superior training and knowledge in the subjects under investigation, they also exhibited higher levels of dissatisfaction with school structures. Additionally, while the variation in teacher self-efficacy is more significant among teachers within a particular school, rather than between schools, unfavourable school conditions and low academic achievement among students in disadvantaged schools (both structurally and socio-economically) can undermine teachers' confidence in their ability to impact teaching and learning (Gümüş and Bellibaş, 2023). This disparity can be attributed to the educational inequalities that exist between public and private schooling in Brazil. Findings from a survey conducted by the Brazilian Institute of Geography and Statistics in 2018 reveal that only 36 per cent of public school graduates enrol in higher education, whereas the rate is nearly 80 per cent for students from private schools (*Folha de S. Paulo*, 2018).

It is important to point out that this research was conducted with teachers in service in schools in the state of São Paulo, which has the best results among the Brazilian states in the last Basic Education Development Index (BEDI) report, both in the early years and in the final years of primary education. The BEDI is an indicator created by the federal government to measure the quality of education in public schools (São Paulo Governo do Estado, n.d.).

Conclusion

Implications and contributions of the study

This study sought to investigate the perspectives and practices of Brazilian in-service primary teachers concerning interdisciplinary pedagogical approaches involving STEAM education, project-based learning and the meaningful integration of science and art-related subjects. The main focus was on interdisciplinarity, given its pivotal role in facilitating the fusion of disciplines and the implementation of project-based learning.

The quantitative data analysis in this study complemented the qualitative insights, serving as a valuable support component. However, the primary objective was to gain a deeper understanding of how teachers in Brazil engage with these areas, perceive their self-efficacy and identify their training needs.

It is evident that in-service training has the potential to enhance teacher self-efficacy, particularly in science (Akerson and Bartels, 2023) and arts (Biasutti et al., 2015; Hauge et al., 2016) where low self-efficacy levels were observed. Comprehensive in-service training programmes can play a crucial role in empowering Brazilian teachers, instilling greater confidence and effectiveness in their pedagogical practices.

There is a pressing need to invest in interdisciplinary training that emphasises project-based learning and focuses on improving competencies in chemistry, physics and arts, where teachers expressed a lower level of effectiveness. This approach aligns with the reported training needs of the interviewees, contributing to the alignment with Brazil's national curricular standards and its commitment to global educational goals, including United Nations Sustainable Development Goal 4 – Quality Education.

STEAM education is a priority on a global scale, as evident from the literature reviewed in this study. In Brazil, this commitment is reflected in initiatives such as UNESCO Brasil's (n.d.) Educa STEM 2030 programme, as well as in various private and public efforts. There remains room for greater cohesion and integration across these initiatives.

Study limitations

The limitations of the study are important to consider, given the relatively limited research history on STEAM education in Brazil:

1. *Exploratory nature*: this study is inherently exploratory due to the nascent state of STEAM education research in Brazil. The small sample size makes it challenging to generalise findings to a broader population.

2. *Subjectivity of perceptions*: the data relied on teachers' subjective perceptions, which can be complex to analyse and generalise. Responses were deeply rooted in each teacher's individual experiences and interpretations of the presented themes.
3. *Conditioned responses*: it was observed that respondents' answers were influenced by their individual conceptual and pedagogical backgrounds. While efforts were made to clarify concepts during interviews, responses remained closely tied to each teacher's unique perspective.
4. *Awareness and knowledge variation*: teachers exhibited varying levels of awareness and knowledge about the terms and approaches discussed. Those with a deeper understanding tended to respond more cautiously, not uniformly expressing high self-efficacy. Instead, they often provided reservations, context or justifications for their responses.

These limitations highlight the need to interpret the findings of the study in the context of the individualised and nuanced perspectives of the participating teachers, recognising the diverse backgrounds and levels of expertise among them.

The transfer value of the study to an international audience

The imperative for accessible professional development (Fackler and Malmberg, 2016) and the enhancement of teachers' self-efficacy beliefs align with global educational priorities. In Brazil, the structure of basic education has exerted an influence on national curricula and educational foundations. Consequently, it is unsurprising that similar needs arise in an educational model where early years teachers must possess diverse skills and contend with shortcomings in their initial training, stemming from the model adopted and the rapid pace of change within the field. By delving into, exploring and further investigating the factors impacting the teacher self-efficacy of teachers in Brazil, particularly in the context of pertinent presented issues, we inevitably raise questions of relevance in other regions worldwide.

Furthermore, the global adoption and practice of the STEAM approach underscore the urgency of these concerns. As STEAM gains prominence globally, it invites contemplation of issues of equitable access to educational opportunities and the development of internationalised curricula that remain responsive to the unique needs of various regions around the world.

Declarations and conflicts of interest

Research ethics statement

The authors declare that research ethics approval for this article was provided by ISPA-Instituto Universitário ethics committee, and ethical procedures were followed throughout the research process.

Consent for publication statement

The authors declare that research participants' informed consent to publication of findings – including photos, videos and any personal or identifiable information – was secured prior to publication.

Conflicts of interest statement

The authors declare no conflicts of interest with this work. All efforts to sufficiently anonymise the authors during peer review of this article have been made. The authors declare no further conflicts with this article.

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