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E-textiles, STEAM and school libraries: Perceptions of primary school teachers

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Abstract
Electronic textiles (e-textiles) are presented as an innovative educational resource that offers teachers diverse opportunities to enrich teaching and learning processes within a STEAM (Science, Technology, Engineering, Arts and Mathematics) framework. This study explores the perceptions of Galician teachers involved in the Creative Library Programme, which aims to advance the innovative school library model by incorporating e-textiles as an educational tool in primary education, as well as their potential role in fostering equity within the STEAM approach. The study adopts an interpretive methodology with a phenomenological-hermeneutic approach, capturing the voices of teachers through an *ad hoc* questionnaire and semi-structured interviews. Findings reveal that teachers considered e-textiles as an ideal pedagogical resource for promoting equity, inclusion, and interest in STEAM disciplines. Moreover, the programme served as the primary framework through which participants were introduced to this resource, thus pointing out its strong perceived relevance for the development of 21st-century skills. Teachers report employing e-textiles in interdisciplinary proposals to introduce students to electrical circuits and programming through creative and artistic means. The principal challenges identified include insufficient training in the field of e-textiles and the limitations imposed by rigid school grammar.

Keywords
Educational programmes; Equal opportunities; Educational technology; Pedagogical innovation; Primary education; Primary school teacher; School library; Skills development.

1. Introduction
Over the past decade, international education policies have promoted the STEAM (Science, Technology, Engineering, Arts and Mathematics) approach, highlighting the importance of fostering early interest in these five areas and addressing them through a skills-based and interdisciplinary methodology. This pedagogical framework is rooted in maker education (Hughes & Kumpulainen, 2021), which advocates for "learning by making" as an active, hands-on, and experiential methodology (Giménez, 2024). As a result, many educational institutions have recently introduced dedicated learning spaces designed to promote 21st-century skills, commonly known as makerspaces (Rouse & Rouse, 2022)

One of the resources commonly utilized in such environments is electronic textiles, or e-textiles (Peppler, 2022) fabrics embedded with electronic and digital components. In line with the rise of the maker movement and the "Do It Yourself" (DIY) philosophy, e-textiles have become increasingly accessible and particularly valuable in STEAM education for their potential to integrate artistic and creative expression within the STEM disciplines (Peppler, 2016). This has led to the development of teaching strategies that explore the effective incorporation of the "A" in STEAM (Aguilera & Vílchez-González, 2024). E-textile activities provide a learning context centered on the creation of physical artefacts, in which learners take an active role in building and expressing themselves consistent with the constructivist principles of learning proposed by Papert (1980). Like educational robotics, e-textiles have been shown to encourage new ways for learners to engage with computing by integrating practices such as sewing and crafting with familiar, everyday materials like textiles and paper. This promotes broader participation in computing-related activities (Jayathirtha & Kafai, 2020). Additionally, e-textiles offer new ways of learning about circuits and electricity, providing a hands-on and engaging introduction to these abstract concepts (Peppler & Glosson, 2013). In support of this, a recent

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systematic review found that e-textiles promote equity within STEAM learning in primary education settings (Guimeráns-Sánchez et al., 2024)

In alignment with this trend, makerspaces have recently been introduced into school libraries (Kim et al., 2022), where the pedagogical value of e-textiles is increasingly recognized (Halverson & Sheridan, 2014). This transformation of the traditional school library is reflected in the IFLA/UNESCO Public Library Manifesto (2022), which highlights the critical role of libraries in developing media and information literacy, supporting both education and lifelong learning areas in which STEAM activities are playing an increasingly significant role (Juliani et al., 2021). In Spain, the current education legislation (LOMLOE, 2020) affirms that teaching staff, including those working in school libraries, should be specifically trained in cross-curricular science and technology education. This vision is being realized in the Autonomous Community of Galicia, where the Regional Ministry of Education, Science, Universities and Vocational Training, through its School Library Advisory Service and the LÍA Plan (Reading, Information, and Learning), has promoted the Creative Library Programme (BC, the Spanish acronym for programa Biblioteca Creativa) since the 2018–2019 academic year. Participating schools receive financial support to acquire materials, equipment, and STEAM-related training workshops for students, transforming libraries into creative learning hubs (Novoa & Pousa, 2024).

Considering that e-textiles as an educational resource a relatively new field of study (Guimeráns et al., 2024), that the literature highlights for a need for further research on the educational implications of the STEAM approach (Aguilera and Vilchez-González, 2024) and that different authors have demonstrated its relevance in continuing education (Sat and Cagiltay, 2024; Searle et al., 2016; Tofel-Grehl et al., 2021) and in the development of *maker* skills in initial and continuing teacher training (Valente and Blikstein, 2019), this study focuses on identifying, analyzing and interpreting the perceptions of teachers participating in e-textile training workshops regarding the educational value they attribute to this resource and its potential to promote equity in the STEAM approach. It also aims to investigate the impact of the workshops on teachers' own teaching practice.

2. Methodology

2.1. Study Design

This research adopts an interpretive design with a phenomenological-hermeneutic approach (van Manen, 2003), appropriate for expanding the understanding of the phenomenon based on the experiences of teachers who took part in the training workshops *E-textiles and New Creative Technologies in the School Library*, conducted within the framework of the BC between the 2019/2020 and 2023/2024 academic years. This methodology incorporates a range of techniques in its pursuit of the “study of the essential meaning of phenomena, as well as the significance and relevance they hold” (Ayala-Carabajo, 2008, p. 411). For this study, data collection involved a combination of an *ad hoc* online questionnaire and semi-structured interviews, aimed at exploring the pedagogical significance of integrating e-textiles into primary school education in the context of STEAM.

2.2. Participants

The study sample comprises teachers from 58 public schools in Galicia participating in the BC who attended the e-textiles workshop between the 2019/2020 and 2023/2024 academic years. One or two teachers from each center participated in these workshops, of whom 62 responded to the open questionnaire. The study sample consists of 53 female and 9 males most of whom were generalist primary teachers (59.7%), with the remainder being early childhood educators (22.6%) and subject specialists (17.7%). The average age of participants was 47.24 years, with 58% reporting more than 20 years of teaching experience. In terms of geographical distribution, the sample represents the four Galician provinces fairly evenly (A Coruña and Pontevedra: 25.8%; Lugo and Ourense: 24.2%). The majority, however, were teachers from rural schools (83.9%).

Three school library coordinators participated in the interviews, whose characteristics are summarized in Table 1.

Table 1
Description and characteristics of the interviewed teachers

ID	Gender	*Age*	Province	Rural/ urban	Teaching experience	Specialty	Getting started with e-textiles
Int.1	F	48	Pontevedra	rural	18 years	Early Childhood education	2020/2021
Int.2	F	43	A Coruña	rural	21 years	Music education	2020/2021
Int.3	M	47	Pontevedra	rural	24 years	Music education	2021/2022

2.3. Instruments and procedures

Two techniques were employed for data collection, both of which foster reflection on lived experiences through description and dialogue (van Manen, 2003): questionnaires and interviews.

An *ad hoc* online questionnaire was created using the Microsoft Forms platform. It consisted of 56 items 78736159Y+1104

divided into four sections: (1) sociodemographic data; (2) role in the school library and introduction to e-textiles; (3) e-textiles in relation to STEAM education and equity; and (4) teaching experience. The instrument was designed based on a systematic literature review on the use of e-textiles in primary education, which helped to identify key themes and served as a theoretical foundation (Guimeráns et al., 2024).

To ensure its validity, the questionnaire was reviewed by five experts in educational technology specializing in STEAM and school libraries, following established validation protocols (Taherdoost, 2016). Based on their feedback, the questionnaire was reorganized, and the wording of several items and response options was refined. The final version was sent via email on 4 June 2024 to the BC coordinators in each of the 58 centers that got involved, who shared it with other teachers who participated in support. The link remained active for three weeks. Participation was voluntary, and respondents were informed about authorship, data use, and the purpose of the study, with consent explicitly requested at the start of the form.

The interview was based on the research objectives. Its design was structured in four blocks: 1) personal-sociodemographic questions, 2) role of the creative library in the introduction to e-textiles, 3) interest and start in STEAM education, and 4) development of an Integrated Documentary Project (PDI, the Spanish acronym for Proyecto Documental Integrado) with e-textiles or electronics and programming as the main resource.

For its implementation, five people, coordinators of the Creative Library, were contacted by email, as they were considered key informants for including e-textiles in their PDI. Three of them agreed to be interviewed, which was conducted by videoconference. At the beginning of the conversation, the participant was informed of the purpose of the interview and its value for the research, as well as the data processing procedure that would be followed. After receiving informed consent, the interview began and an audio recording was made for retrieval and subsequent transcription.

2.4. Data Analysis

Quantitative data from the questionnaire were organized in a spreadsheet and analyzed using IBM SPSS Statistics (version 25). Descriptive univariate analyses (frequencies, means, and percentages) were conducted for the full sample.

The audio recordings of the interviews were transcribed for analysis. The qualitative data corpus, consisting of the transcripts and the spreadsheet generated by Forms, was imported into the qualitative analysis software ATLAS.ti v24.2.0 (2024) for analysis. The process carried out follows the content analysis method. Following the principles established by Strauss and Corbin (2002), the data were coded inductively and interpretively through open coding, selecting significant segments of information (quotes) for the proposed objectives, resulting in 16 categories of analysis (codes) organized into 4 dimensions (Table 2). Next, in the axial coding phase, relationships between the categories were established. These processes allow the central categories of the analysis to be identified, those with the greatest foundation (frequency-quotes) and density (number of relationships), favoring the generation of theory.

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Table 2
Dimensions and categories derived from content analysis, codes, and their definitions.

Dimensions	Category	Code	Definition
The potential of e-textiles	Educational value of the resource	VALRED	Excerpts mentioning the value of e-textiles for education
	Introduction Programming and circuits	INPROG	References to the potential of e-textiles for learning about electrical circuits and programming
	Teamwork	TREQ	Comments on suitability for teamwork
	Student motivation	MOTALUM	Comments on student motivation in activities with e-textiles.
	Student emotions	EMOCALUM	References to emotional issues that arise in the use of e-textiles
Equity	Access to STEAM	ACCSTEAM	References to the affordability and accessibility of STEAM education
	Gender gap	GEN	Excerpts that refer to gender equality, female role models in STEAM, or stereotypes associated with e-textiles
	Inclusion	INCL	References to the participation of all people regardless of their conditions or abilities
Challenges for teaching	Teacher professional development	DEPR	Excerpts referring to the teachers' personal growth
	Teacher training	FOPR	Excerpts that refer to gender equality, female role models in STEAM, or stereotypes associated with e-textiles
	Teacher job stability	ESPR	References to frequent changes in teaching staff each school year
	Teacher commitment	COMPR	References to the rejection of e-textiles by some members of the faculty
	School grammar	GRAMESC	Fragments on classroom management, grouping, time and space
	Material resources	RECMAT	References to the importance, necessity, or lack of material resources
Institutional commitment	*Creative Library* Programme	BC	References to the BC or to the library as a *maker* space at the educational center.
	Investment Libraries	INVBIBL	References to the budgetary investment of the Galician School Library Advisory Service.

3. Results

The results are presented in accordance with the dimensions of analysis that emerged from the qualitative data. Each section is organized around a central category, with the exception of the dimension *Institutional Commitment*, which emerged transversally and is discussed within the section on *Challenges for Teaching*. The findings combine qualitative data derived from content analysis with quantitative data drawn from the closed questions of the questionnaire.

3.1. Potential of E-textiles in Primary Education

In relation to the potential of e-textiles, teachers consistently emphasized the educational value of this resource (Figure 1).

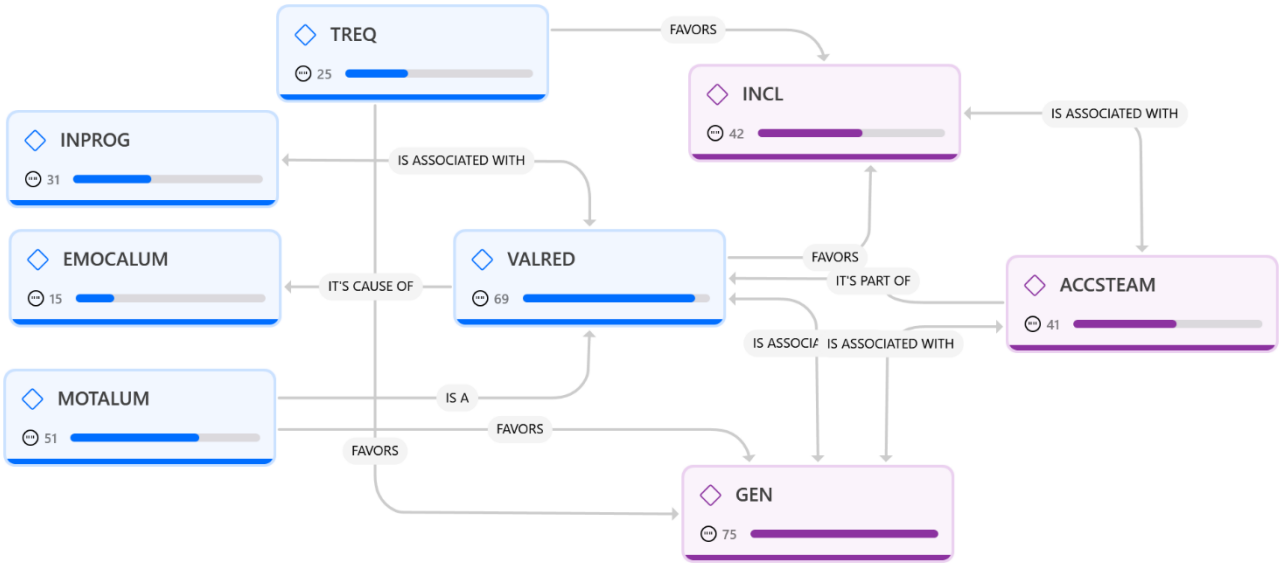

Figure 1. Semantic network of the central category Value of the resource

These findings are closely linked to the promotion of creativity: "*Well, I find them very interesting, especially because they give us the opportunity to work on creativity with the children, so that they can develop their creativity and imagination and carry out their own projects*" (Int.1) ; "*the presence of e-textiles opens countless doors to teachers' creativity, enabling any child to develop within science and technology, regardless of their economic, social, or cultural background* " (Teacher 11).

Teachers often associated this creative potential with other aspects such as motivation, communication, and divergent thinking. E-textiles were described as *"a novel, motivating tool that fosters children's creativity and is a highly effective classroom resource"* (Teacher 35); and "*as activities that encourage spontaneous communication and creativity, so that each product is different from another, thus obtaining intrinsic value"* (Teacher 13).

Other frequently cited benefits include '"*analysis, design, execution, and problem-solving"* (Teacher 38), as well as the tangible, hands-on nature of the materials: "*they enjoy being able to create, manipulate, and programme by themselves, recognizing that they are the ones doing the making*" (Teacher 42) and point out that *"It reinforces fine motor skills in children when sewing*" (Teacher 30). However, this was also mentioned as a practical challenge "*there's a lack of fine motor skills when using a needle and thread, as sewing is not taught in early childhood education*" (Teacher 48).

This overall positive view is supported by the responses to the questionnaire (Figure 2).

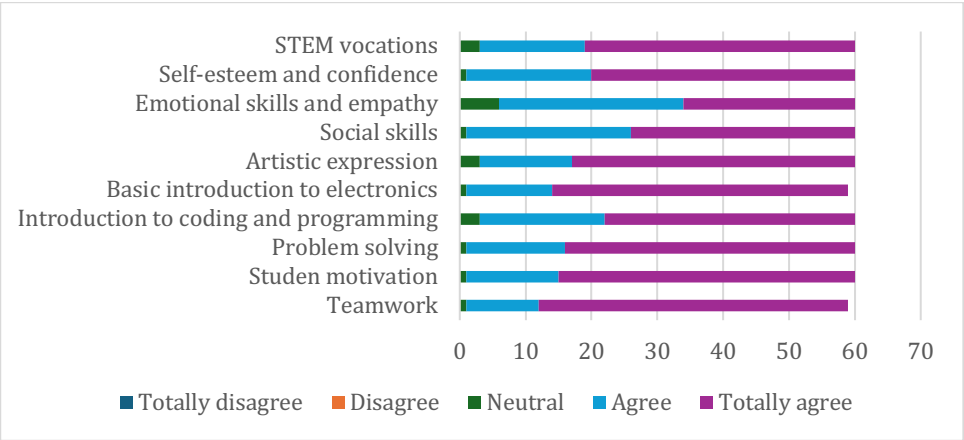

Figure 2. Likert scale frequencies on the value of e-textiles

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Figure 2 illustrates a high level of agreement among participants that e-textiles are an effective tool for introducing basic concepts in electronics and programming ($\bar{x}$ = 4.68). This view is further reflected in the content analysis: "*e-textiles, due to their simplicity, provide a gateway into programming and electronics*" (Teacher 12), "*it is a first step towards understanding the infinite possibilities of electronics and programming*" (Teacher 8), and it also allows for a tangible introduction, "*it is a fun and very visual way to understand the mechanisms related to electronics and programming by exposing each part of the circuits and placing them in full view"* (Teacher 39), "*a fantastic way to understand circuits in a hands-on way and a very good experience for moving from analogue circuits to the introduction of programming boards"* (Teacher 47).

Educators also expressed strong agreement regarding the wider benefits of using e-textiles in school libraries: boosting students' self-esteem and confidence ($\bar{x}$ = 4.65), increasing their motivation ($\bar{x}$ = 4.73), sparking interest in scientific and technological subjects ($\bar{x}$ = 4.63), and fostering teamwork ($\bar{x}$ = 4.78).In this regard, teachers point out that "*successfully completing a simple circuit gives them a positive self-image, improves their self-esteem, and motivates them to take on more complex projects*" (Teacher 35), "*they are amazed by the results of their efforts, which enhances their self-confidence, collaboration, and idea-sharing"* (Teacher 14), "*they feel a strong sense of achievement upon completing the task. At times, they doubt themselves, but in the end, they succeed, which builds confidence*" (Teacher 10) .Additionally, e-textiles were regarded as *"highly motivating for students"* (Teacher 19),*"they are motivated to work with fabrics because they are a basic yet engaging material* (Teacher 23) and the benefits of collaboration were also highlighted, "*they learn from each other, discover new skills, and overcome frustrations*" (Teacher 17).

3.2. Equity

Teachers stressed the role of e-textiles in addressing gender gap (Figure 3).*"Combining a 'traditionally female' task such as sewing with a 'traditionally male' one such as building circuits brings both genders closer together and eases access to areas that might initially seem inaccessible, such as STEAM "* (Teacher 27).While some initially observed gender-based preferences *"at first, the boys were only interested in programming, and the girls preferred sewing"* (Teacher 8), teachers later recognized e-textiles as *"a powerful and enjoyable tool for addressing gender disparities"* (Teacher 1). Others noted that: "*It's not about gender; it's about creativity and individual strengths*" (Teacher 17), "*gender becomes irrelevant*" (Teacher 12).

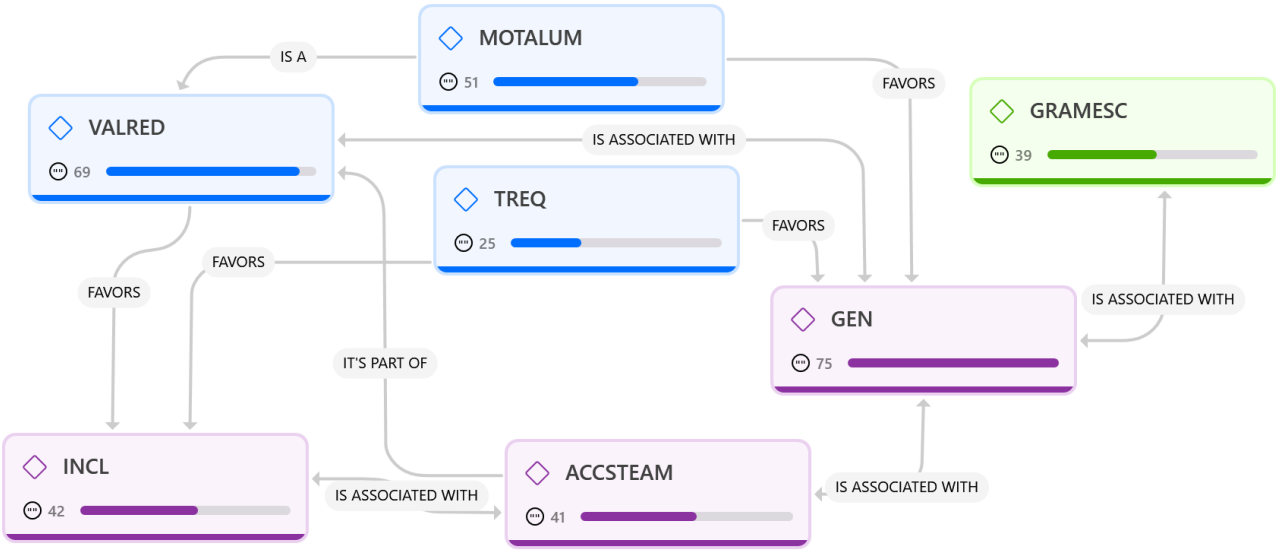

Figure 3. Semantic network of the central category Gender Gap

The analysis shows that this category is linked to teamwork *"male and female students work equally with each other. The male students do the cutting and sewing and then the female students do the programming,*

and vice versa" (Teacher 8) and to motivation "*for our female students, meeting a female Galician role model like Paola was incredibly inspiring*" (Teacher 45).

The value of e-textiles in promoting equality is also highlighted, both in terms of promoting access to STEAM education, as " *it uses a material that is very accessible to all students"* (Teacher 12), and in terms of including all students in the activities regardless of their circumstances, as *"it allows everyone at the school to be present, participate and learn*" (Teacher 2).

The quantitative findings (Figure 4) further confirm the value that teachers attribute to e-textiles in promoting equity.

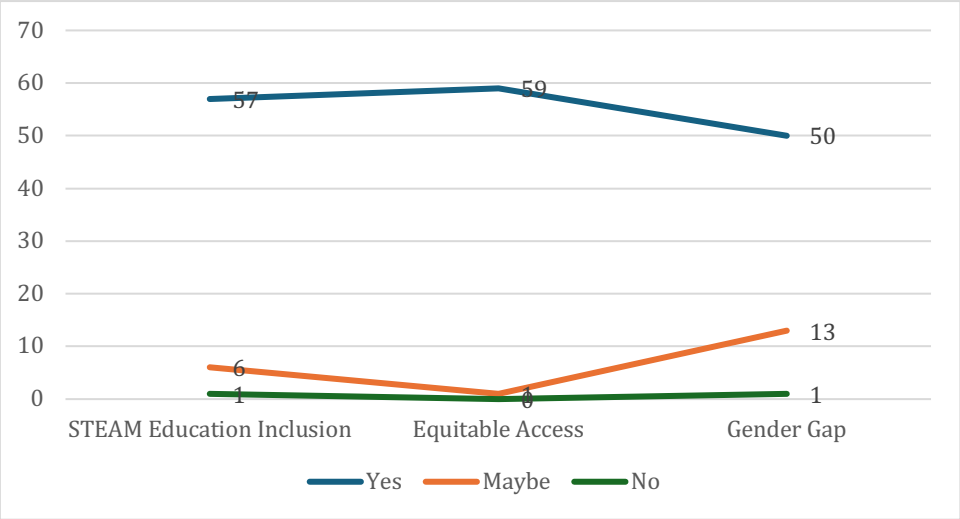

Figure 4. E-textiles frequencies for equity

3.3. Challenges for Teaching

With regard to the dimension of Challenges for teaching, the central issue identified is teacher training, which was deemed *"essential"* (Teacher 7). This concern is prominent in participants' responses (Figure 5): "*We need training in order to be able to train"* (Teacher 18), this is key because 'once teachers see the possibilities, everything runs smoothly' (Teacher 12). They emphasize that " *there should be more training for teachers because resources alone are not enough"* (Teacher 32).

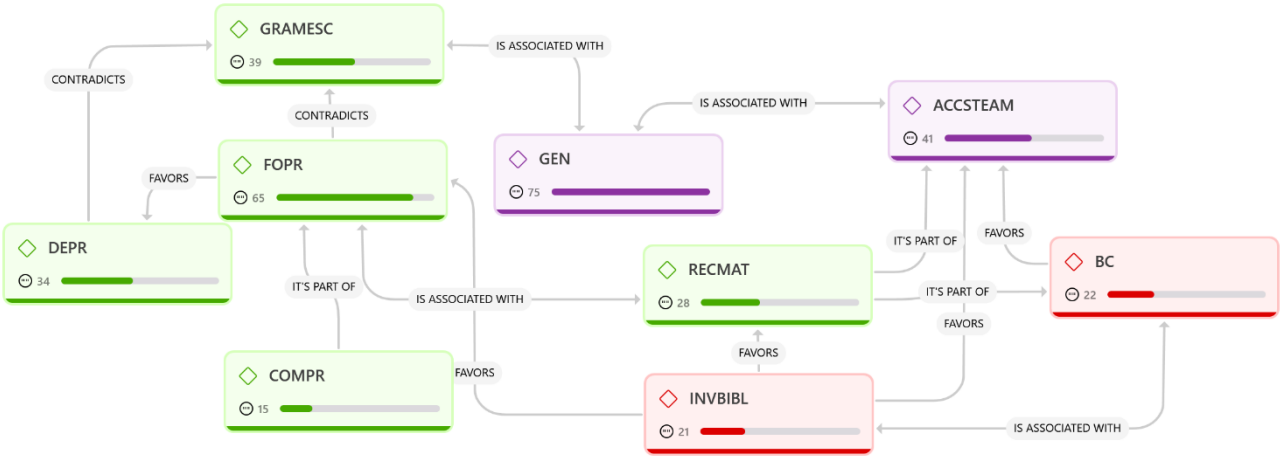

Figure 5. Semantic network of the central category Teacher Training

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Teacher training was viewed as key to professional development, *"training in e-textiles opened doors for me and helped me overcome my fear of an area I knew nothing about. Now, I feel more confident in the field of technology*" (Teacher 11); "*the more knowledge, the more confidence*" (Teacher 7). "*Let's say I'm more daring. I jump in with the children and learn alongside them*" (Int.1). Continuing education allows them to leave their fears behind. This fear, together with a lack of interest, were cited as the main reasons given for the lack of commitment among their colleagues in the field of e-textiles: *"teachers often avoid programming and electronics due to fear or lack of knowledge*" (Teacher 27), "*I feel like, because I don't master the subject, I'm not going to jump in and work on it with my students because I don't fully understand it*" (Int.1). To address the challenge of "*involving teachers*" (Teacher 25), "*we need training and genuine interest*"(Teacher 20).

Another significant challenge lies in the structural rigidity of educational institutions, particularly timetabling and the availability of suitable spaces. Specifically, they state that "*the biggest challenge is finding time in the curriculum* "(Teacher 33). The "issue of time is fundamental", because integrating e-textiles involves designing "*activities that require a different timing, which are learned through experience* (Teacher 5). Teachers call for "*adequate spaces to be able to carry out this type of task*" (Teacher 35) and point to the challenge of integrating this resource when "*many teachers are still tied to curricula and textbooks*" (Teacher 14). They also stress the need to break away from traditional groupings and isolated subjects, proposing "*mixed and rotating groupings*" (Teacher 1) and providing *"an interdisciplinary approach, which is why we have it in the library and it is available to everyone*" (Int. 3).

They also point to the lack of material resources or their high economic value as another challenge they face in integrating e-textiles into educational practices. In this regard, there are major contradictions, both in the discourse and in the responses to the questionnaire (Figure 6), which show a disparity of opinions regarding the provision of resources available in the school libraries of their centers. In this regard, we find teachers who point out that "*these materials are not difficult to obtain*" (Teacher 23) and that "*they are affordable and inexpensive*" (Teacher 27), while others observe that "*the biggest challenge is economic; the materials are expensive for the available budget*" (Teacher 16).

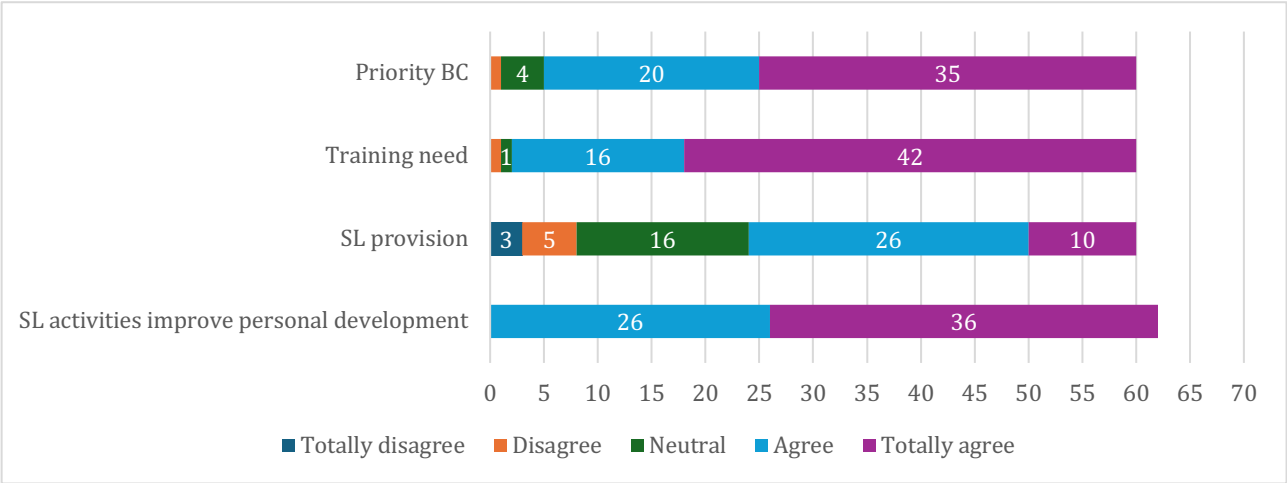

Figure 6. Likert scale frequencies for e-textiles in the school library

Note: BC (Creative Library Programme). BE (School Library)

Figure 6 supports teachers' claims, particularly regarding the importance of training in overcoming institutional rigidity ($\bar{x}$ = 4.58). In this regard, teachers emphasize that '"*teacher training is part of the key to the success of a programme*" (Teacher 5).

The BC has served as the main platform for introducing e-textiles to 84% of participating teachers, primarily through workshops and training sessions held since its launch in 2018. Fifty-six per cent reported having implemented e-textile-based educational activities in both the school library and classroom.

"We connected local archaeological heritage with e-textiles in a project we called *Petrotéxtiles*. We began with nearby petroglyphs in Louro, which led us to an interdisciplinary project across all subject areas" (Int.2) (see Figure 7).

Figure 7. Images from the PDI "Petrotéxtiles," which combines Art, Engineering, Technology, History, and Cultural heritage in interactive textiles.

The quantitative data (Figure 8) reinforce the teachers' views, positively assessing investment and teacher training, both in terms of promoting equity in STEAM education and in building confidence and introducing students to electronics and programming.

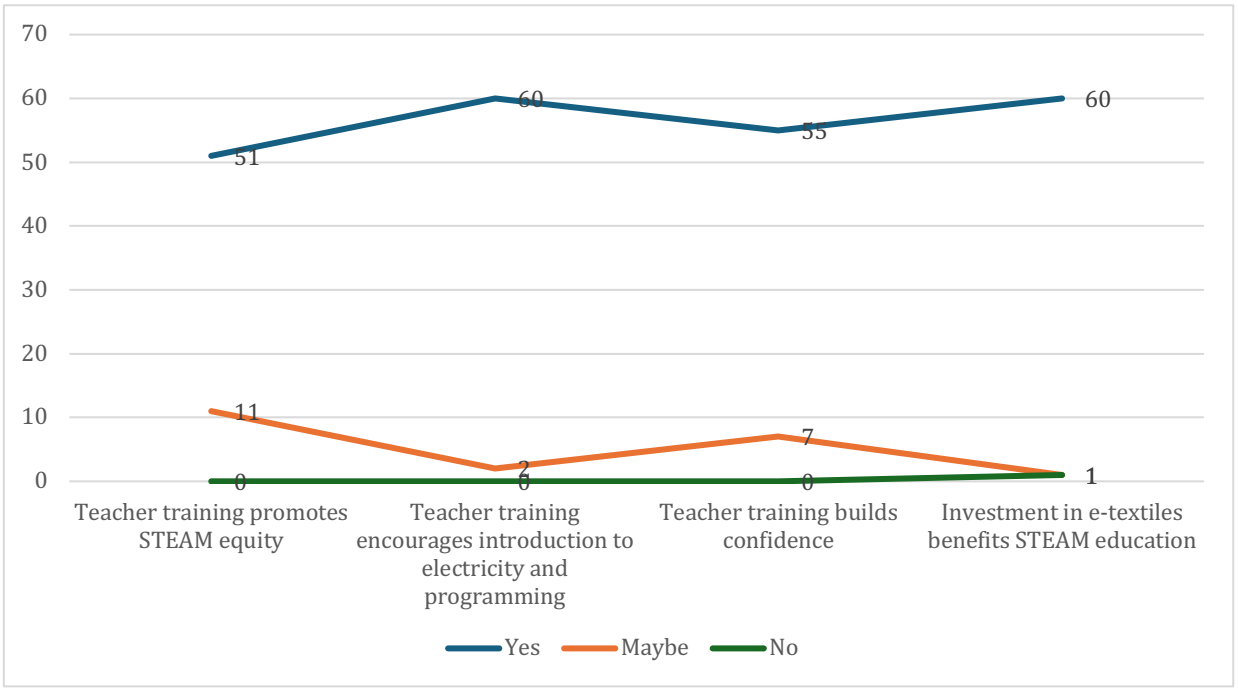

Figure 8. Frequencies of teacher training and investment

A final challenge, specific to rural schools, emerged during interviews, a lack of staff continuity. The constant change in teaching staff makes it difficult to maintain continuity in ongoing projects. *"It's something*

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we have to revisit every few years. We have to start projects over again every few years due to frequent staff turnover" (Int.3)

> "We struggle here in rural areas. For example, the girl who requested to teach English here has already asked to be transferred because she knows we're working like this. That has saved us because, you see, the way things are and the fact that there are no permanent positions here, it's a mess for me." (Int.2)

4. Discussion and Conclusions

This study aims to explore teachers' perceptions of the educational value of e-textiles, both in terms of their potential in STEAM education and their contribution to fostering equity.

With regard to the perception of e-textiles as an educational resource, the results indicate that the majority of participating teachers consider them a highly engaging tool that enhances students' interest in STEAM subjects and fosters the development of key 21st-century competencies. Previous research supports these findings, highlighting e-textiles as a motivating resource (Jayathirtha & Kafai, 2020) that promotes interest in STEAM pathways (Rigden et al., 2019). Similarly, most teachers reported that e-textiles enable students to design interactive, tangible projects that facilitate an introduction to basic electronics and programming through artistic and creative expression (Peppler & Wohlwend, 2018). This aligns with the integration of the 'A' in STEAM (Aguilera & Vílchez-González, 2024) and contributes to the development of computational thinking (Fields et al., 2019). Participants also underlined the pedagogical value of new materials that support fine motor development and hand–eye coordination from an early age. These results are consistent with studies that advocate the use of conductive thread and similar materials to nurture such skills, while recognizing the essential role of teacher support in managing moments of difficulty or frustration (Hughes & Morrison, 2018).

In terms of equity, the results suggest that most teachers perceive e-textile projects as promoting collaborative work on equal terms. Fields and Kafai (2023) provide empirical evidence for the equitable potential of such activities within STEAM learning. Teachers in this study pointed to the inclusive nature of e-textiles, as they offer diverse modes of participation and engage pupils with varying interests and abilities, thus helping to break down traditional gender stereotypes. These results echo findings from Searle et al. (2019), who observed that such initiatives enable female students to identify with STEM fields, even if not directly with science subjects. The results show a positive impact on reducing the gender gap, as it allows for the integration of cultural issues and other disciplines. This interdisciplinary connection contributes to greater cognitive development, as well as emotional and behavioral benefits (Aguilera & Vilchez-González, 2024), which promotes access to technology for more diverse learners.

When analyzing the opportunities and challenges associated with teaching, the results show that most of the teachers who have implemented e-textile projects and activities appreciate their participation in the BC and recognize the educational potential of this resource. Many have continued to develop new proposals as a result. In this respect, García et al. (2019) argue that the perceived benefits of such projects for pupils can strengthen teachers' sense of self-efficacy and belief in their practice, encouraging further pedagogical innovation.

In keeping with this, participants identified continuing professional development as one of their main concerns, acknowledging that the current educational paradigm demands changes in teaching and learning methodologies (Greca & Meneses, 2018). This challenge is compounded by the need to acquire new technological and pedagogical skills (Mishra & Koehler, 2006; Herro et al., 2022). While the training sessions and workshops—and the resources made available—helped to foster teacher familiarity with e-textiles (Peppler, 2016), many respondents highlighted that rigid institutional structures and a lack of ongoing, subject-specific training hinder the effective integration of such resource. Research on the implementation of resources for STEAM education points to time constraints as a major barrier (Rich et al., 2019), both for classroom application and for adequate teacher training (Herro & Quigley, 2016). Moreover, insufficient expertise and the need for appropriate pedagogical strategies remain key challenges (Rich et al., 2019). Srikoom and Faikhamta (2018) emphasize that access to resources and workshops alone is not sufficient—high-quality, specialized training is essential.

The main limitations of this study focus on the representativeness of the quantitative data, especially the sample size and the restriction of the territory covered, which is limited to a single Autonomous Community (Galicia). Future research, in addition to evaluating a large sample study, it should consider broader geographical contexts where the school library is similarly being reimagined as a creative learning space and analyze the perspectives of other teachers and other voices regarding this educational resource.

In conclusion, the present analysis highlights the significant educational potential of e-textiles, which are perceived as a tangible and manipulative educational resource, close to everyday life, practical, and creative. It also reveals the relevance of this resource for sparking students' interest and curiosity in programming and electronics from an equitable approach, which raises the need to incorporate it into teaching and learning processes as a key resource for STEAM education. Finally, the study emphasizes the need for teacher training, beyond simply providing equipment. High-quality ongoing training, such as that offered by the BC, should include the necessary support to build confidence and trust among education professionals in the use of innovative resources that help prepare students for the challenges of the 21st century.

Authors' contribution

Paola Guimeráns Sánchez: Conceptualisation; Methodology; Data collection and management; Manuscript writing (review and editing). **Almudena Alonso-Ferreiro:** Methodology; Data analysis; Manuscript writing (review and editing).

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