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TRAINING PATHWAYS FOR TEACHERS IN STEAM EDUCATION: KNOWLEDGE AND EXPERIENCES BETWEEN BRAZIL AND PORTUGAL

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Abstract: This article analyzes the perceptions, knowledge, and applicability of the STEAM approach and continuing teacher education among Brazilian and Portuguese participants. The CSD technique was used to analyze open-ended questionnaire responses. The results revealed that 71.8% of the participants were unfamiliar with the STEAM approach. However, those who had experience encouraged interdisciplinary activities and student participation.

Keywords: STEAM; Internationalization; Teacher Training.

TRILHAS FORMATIVAS PARA DOCENTES EM EDUCAÇÃO STEAM: SABERES E EXPERIÊNCIAS ENTRE BRASIL/PORTUGAL

Resumo: O artigo objetiva analisar a percepção, o conhecimento e a aplicabilidade dos participantes brasileiros e portugueses, no que tange a abordagem STEAM e a formação continuada de professores. Para o tratamento das respostas abertas emitidas pelos respondentes no questionário, usou-se a técnica CSD. Os resultados mostram que 71,8% dos participantes desconheciam a abordagem STEAM, e os que possuíam experiência incentivam atividades interdisciplinares e a participação do aluno.

Palavras-chave: STEAM; Internacionalização; Formação de Professores.

ITINERARIOS DE FORMACIÓN PARA DOCENTES EN EDUCACIÓN STEAM: CONOCIMIENTOS Y EXPERIENCIAS ENTRE BRASIL/PORTUGAL

Resumen: El objetivo del artículo es analizar la percepción, el conocimiento y la aplicabilidad del enfoque STEAM y de la formación continua del profesorado entre los participantes brasileños y portugueses. Para tratar las respuestas abiertas proporcionadas por los encuestados en el cuestionario, se utilizó la técnica CSD. Los resultados muestran que el 71,8 % de los participantes desconocía el enfoque STEAM, pero los que tenían experiencia fomentaban las actividades interdisciplinares y la participación del alumnado.

Palabras clave: STEAM; Internacionalización; Formación de Professores.

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1 INTRODUCTION

This article portrays the experience resulting from training activities derived from projects developed within the scope of the Research Group on Education, Technologies, and Digital Culture (GRUPETeC - CNPq/UNINOVE), with a focus on: (1) "Robotics, Computational Thinking, and Digital Technologies in Basic Education: Enhancing Learning and Skills in Processes of Resignification of Science Teaching," which was developed from November 2019 to October 2022. This project received funding from the National Council for Scientific and Technological Development (CNPq) and the Ministry of Science, Technology, Innovations and Communications (MCTIC) through the Universal Call MCTIC/CNPq Notice No. 05/2019 - Science in School Program - Science Teaching in Basic Education — and support from Nove de Julho University (UNINOVE); (2) "Creative and Sustainable Robotics in the Development of Professional and Technological Education Integrated with High School: Enhancing Projects in a STEAM Approach," developed since February 2023 with support from the Basic Education Research Program (PROEDUCA - FAPESP/SEDUC) Call for Proposals and Nove de Julho University (UNINOVE); (3) "STEAM Education: A Collaborative Construction with Sustainable Educational Robotics," which has been in progress since March 2023. This project is supported by the National Council for Scientific and Technological Development (CNPq) according to CNPq Call No. 09/2022 - Research Productivity, in partnership with Nove de Julho University (UNINOVE).

Given this scenario, this study aims to analyze the perceptions of Brazilian and Portuguese participants at an event on the STEAM[1] approach and continuing teacher education, regarding the contributions of this approach to the development of new knowledge and its applicability. The text briefly discusses an international continuing teacher education initiative led by Brazilian and Portuguese educators. This initiative provided an opportunity for participants to exchange experiences and knowledge. Reaching its fifth edition, this training model strengthens relationships between professionals from Portuguese-speaking countries and demonstrates the affinity and international interest in the topic, as well as the desire for changes in pedagogical practices that significantly influence teaching and learning. Notably, a common theme among these projects was the focus on

[1]Acronym in English for Science, Technology, Engineering, Arts and Mathematics. STEAM aims to integrate these areas of knowledge into practical, challenging, and interdisciplinary activities. Rather than teaching each subject in isolation, STEAM promotes projects that combine scientific, technological, engineering, mathematical, and artistic concepts to solve real-world problems or develop creative products.

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continuing teacher education in the use of digital information and communication technologies (DICTs) in conjunction with pedagogical practices. There was an emphasis on using educational robotics in basic education through STEAM-based project development.

In this sense, two training pathways aimed at teachers were developed between 2020 and 2021, entitled “I Ciclo de Trilhas Formativas: A Formação Continuada e em Serviço de Professores em Tempos de Educação On-line” and “II Ciclo de Trilhas Formativas: Oficinas para a Formação Tecnológica de Professores" (I Cycle of Training Pathways: Continuing and In-Service Training of Teachers in Times of Online Education” and “II Cycle of Training Pathways: Workshops for the Technological Training of Teachers). These pathways aimed to provide environments for continuing teacher training in the use of digital technologies, robotics, and computational thinking integrated with pedagogical practices in the context of basic education.

In 2023, the III Cycle of Training Pathways: "Workshops and Training Pathways for Teachers: Dialogues and Practices" took place, which aimed to promote another edition of these training pathways. Now, with an international focus, the Universidade Aberta of Portugal (UMCLA - CLA of Coruche and Montijo) partnered with GRUPETeC to promote continuing education for teachers in both countries. In the first half of 2024, this partnership resulted in a training event titled "IV Cycle of Training Pathways: Teacher Training in Times of STEAM Education," which included participants from Portugal, Angola, Mozambique, and Brazil. This demonstrates that internationalization strengthens a more open, flexible, transdisciplinary, and innovative teaching approach by bringing together different content, practices, and contextualized examples (Barros, 2023, p. 26).

Before continuing, it is important to understand the concept of internationalization. According to Okada (2023, p. 36), one of the initial definitions of internationalization was presented by De Wit (1997) as "a process of integrating an international and intercultural dimension into teaching, learning, research, outreach, and other institutional functions and services." Thus, the processes of internationalizing education for development, cooperation, and the exchange of epistemological and scientific knowledge must be considered, as they present limitless opportunities.

According to Barros (2023, p. 30, translated by us),

> There are numerous positive aspects of internationalization, including the promotion of diverse languages and the expansion of a faculty with international experience, expertise, and credentials. This contributes to greater recognition of the institution. These qualities attest to the institution's excellence and international standing, facilitating the integration of students, researchers, faculty, and non-teaching staff. Internationalization fosters a multicultural and multilingual environment and high interdependence.

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The author further adds that

> [...] these processes update the teaching function in the exercise dedicated to constructing classes. They involve planning with the introduction of new content with unusual theoretical and methodological standards, the use of updated tools and applications, and the construction of diverse scenarios and strategies (Barros, 2023, p. 30, translated by us).

In the field of methodological foundations, there are reasons to implement the STEAM approach in the classroom since it aligns with the competencies and skills required by the Brazil's National Common Curricular Base (BNCC) (Brasil, 2018), even though the term "STEAM" is not mentioned in the document. To illustrate the connection between the BNCC and STEAM, the following comparative table was developed.

Chart 1 – Dialogue between BNCC and STEAM

Aspect	BNCC	STEAM
Interdisciplinarity	It encourages integration between areas of knowledge to promote meaningful learning.	Integrates science, technology, engineering, arts and mathematics in interdisciplinary projects.
Digital Culture and Technology	It provides for competence 5: critical and creative use of digital technologies in everyday life and at work.	Uses digital technologies as a central tool for problem-solving and creation.
Real Problem Solving	It encourages the use of active methodologies to resolve everyday and societal issues.	It is based on solving real problems through practical and collaborative projects.
Socioemotional Skills	Develops creativity, critical thinking, communication and collaboration.	Develops creative, communication and teamwork skills in practical projects.
Comprehensive Training	It aims to develop knowledge, skills, attitudes and values for action in society.	Promotes balance between technical (rational) and creative (emotional) skills.

Source : Prepared by the authors (2024).

Based on the above data, this stage outlines the methodological approach adopted for the 2024 launch of this training process, which aims to develop new knowledge about STEAM education. Then, the results are presented and discussed, followed by final considerations, acknowledgments, and references.

2 DESCRIPTION OF THE TRAINING EXPERIENCE

The IV Cycle of Training Pathways, themed "Teacher Training in Times of STEAM Education," took place on April 10, 2024. The event had 159 registered participants, with 87 active participants, of whom 68 responded to the satisfaction/evaluation

questionnaire. The schedule is presented in Table 2:

Chart 2 - Event schedule, with the topics covered in the lectures.

Time	Speaker	Theme
BR: 1:30 PM – 1:40 PM PT: 5:30 PM – 5:40 PM	João Barnabé (Coordinator of the CLA of Coruche of Universidade Aberta of Portugal (UAb -PT) Lara Caeiro (Coordinator of the Montijo CLA of Universidade Aberta of Portugal UAb -PT)	Welcome/General Information
BR: 1:40 PM – 1:55 PM PT: 5:40 PM - 5:55 PM	Adriana Aparecida de Lima Terçariol (GRUPETeC Leader)	Training Pathways: University, School and Research
BR: 1:55 PM – 2:10 PM PT: 5:55 PM - 6:10 PM	Daniela Melaré Vieira Barros (Universidade Aberta of Portugal (UAb -PT)	Pedagogical Internationalization
BR: 2:10 PM – 2:25 PM PT: 6:10 PM - 6:25 PM	Thais de Almeida Rosa (GRUPETeC/Passionist College SP da Cruz)	STEAM Education: Principles and Practices
BR: 2:25 PM – 2:40 PM PT: 6:25 PM - 6:40 PM	Ronaldo Lasakoswitsck (GRUPETeC)	Overview of Training of Teachers in Times of STEAM Education: Brazil
BR: 2:40 PM – 2:55 PM PT: 6:40 PM - 6:55 PM	Ana Maria Mouraz Lopes (UAb /Portugal)	Teacher Training and the STEAM projects using Technologies
BR: 2:55 PM – 3:10 PM PT: 6:55 PM – 7:10 PM	Adriana Aparecida de Lima Terçariol (GRUPETeC) Elisangela Aparecida Bulla Ikeshoji (IFSP-Birigui)	Moment of Interaction Comments/Questions/
BR: 3:10 PM – 3:25 PM PT: 7:10 PM – 7:25 PM	Romeo Affection (GRUPETeC/CPS-SP)	Educational Robotics: A Experience in an Integrated Technical High School
BR: 3:25 PM – 3:40 PM PT: 7:25 PM – 7:40 PM	Maribel Miranda-Pinto (UAb /Portugal)	Educational Robotics, Thought Computational and Innovation
BR: 3:40 PM – 3:55 PM PT: 7:40 PM – 7:55 PM	Lilian Amatucci Gazoti (Inova – Paula Souza Center)	Creativity and Entrepreneurship in Academic Training with PBL and STEAM
BR: 3:55 PM – 4:05 PM PT: 7:55 PM – 8:05 PM	Adriana Aparecida de Lima Terçariol (GRUPETeC) Elisangela Aparecida Bulla Ikeshoji (IFSP-Birigui)	Moment of Interaction Comments/Questions/
BR: 4:05 PM–4:15 PM PT: 8:05 PM – 8:15 PM	Adriana Aparecida de Lima Terçariol (GRUPETeC) Elisangela Aparecida Bulla Ikeshoji (IFSP-Birigui)	Interest (Working Groups) Evaluation Form/Attendance List
BR: 4:15 PM – 4:30 PM	Daniela Melaré Vieira Barros (Universidade Aberta of Portugal (UAb -PT)	Acknowledgments/Closing

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PT: 8:15 PM – 8:30 PM	João Barnabé (Coordinator of the CLA of Coruche of Universidade Aberta of Portugal (UAb -PT) Lara Caeiro (Coordinator of the Montijo CLA of Universidade Aberta of Portugal (UAb -PT)	

Source: Research data (2024, translated by us).

This study was conducted using a qualitative and descriptive methodology. A questionnaire was administered via Google Form immediately after the online meeting to collect data. The form aimed to gather information about the organization of the event, the contribution of the topics to the development of new knowledge and technological competencies, and the applicability of these competencies. Of the 68 responses recorded at the end of the form, four were excluded from the final spreadsheet because the respondents indicated that they did not wish to participate in the research. Thus, the responses of the 64 participants who consented to the anonymous use of their data for academic purposes were considered.

The questionnaire consisted of two parts. The first part used closed-ended, multiple-choice questions to identify the respondents' profiles. The second part used open-ended questions with no content restrictions to capture participants' perceptions of the opportunities created by the lectures' content. Data obtained from each profile were analyzed and described by developing graphs illustrating the frequency distribution of responses. The content of the open-ended questions was analyzed using the Collective Subject Discourse (CSD) technique[2].

In the following section, the results obtained are presented and pertinent discussions are held to achieve the objectives of this article.

3 PRESENTATION AND DISCUSSION OF RESULTS

Regarding the participants' country of residence, the majority (42) indicated that they resided in Portugal. Of the remaining respondents, 20 mentioned Brazil as their country of residence, while 1 indicated being a resident of Angola and another in Mozambique, as can be seen in Graph 1.

[2] The Collective Subject Discourse (CSD) is a technique for tabulating and organizing qualitative data, developed by Lefèvre and Lefèvre in the late 1990s. It allows us to understand the thoughts, representations, beliefs and values of a collective on a given topic using scientific methods, and has demonstrated its effectiveness for processing and expressing collective opinions.

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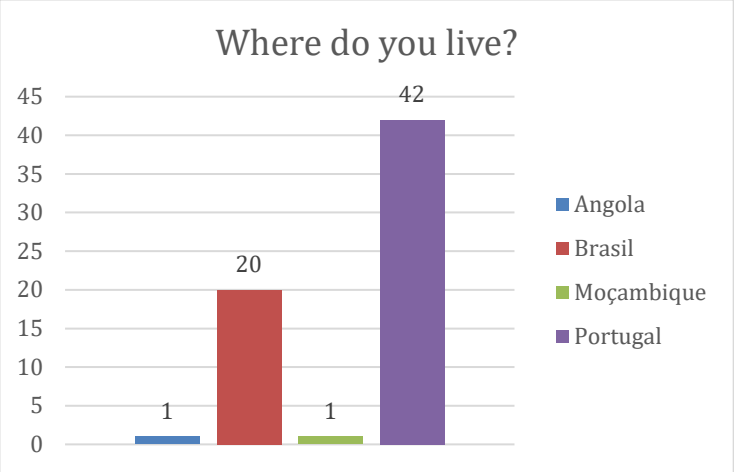
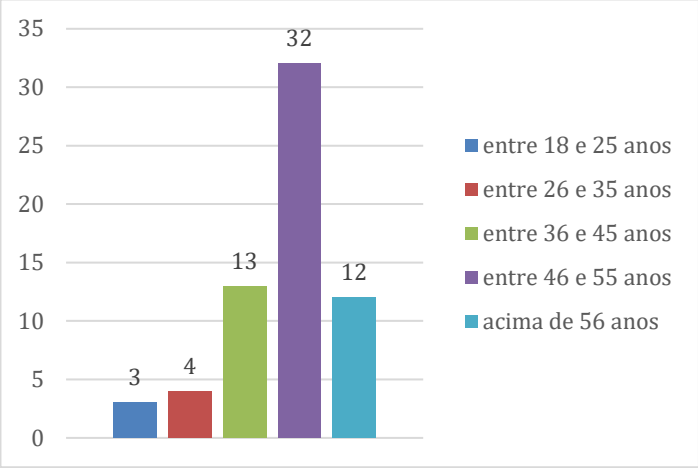
Graph 1 - Country of residence of participants.



Source: Research data (2024).

In relation to age group, the majority (32) stated that they were between 46 and 55 years old, as shown in Graph 2:

Graph 2 - Participant age range.



Source: Research data (2024).

Regarding the event's assessment, according to Graph 3, most respondents expressed "very satisfied" in all evaluated dimensions, namely thematic adequacy (44%), dissemination (32%), organization (43%), and informational content (42%). It is worth noting that these data are supplemented by the number of responses in the "satisfied" category: thematic adequacy (19), dissemination (32), organization (20), and informational content (21). The total for the "very satisfied"

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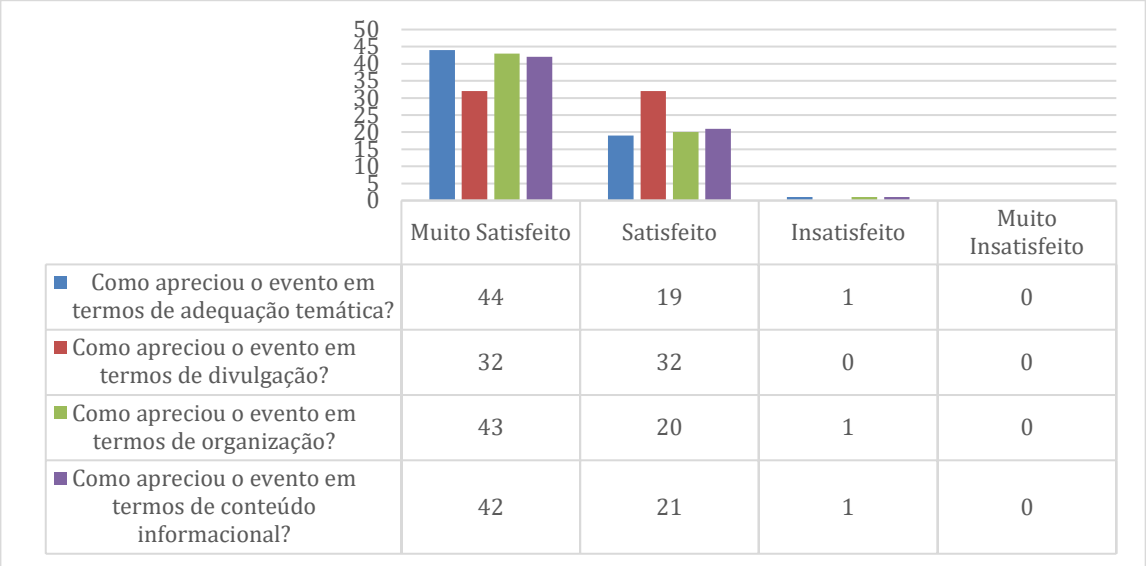
and "satisfied" categories in the evaluated dimensions reinforces the idea that the event met the participants' expectations. Only one indication of dissatisfaction was recorded for the following dimensions: thematic adequacy, organization, and informational content.

Graph 3 - Level of appreciation of the event.

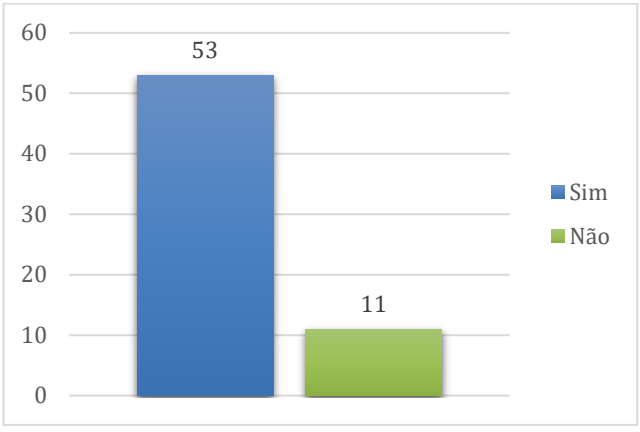


	Muito Satisfeito	Satisfeito	Insatisfeito	Muito Insatisfeito
Como apreciou o evento em termos de adequação temática?	44	19	1	0
Como apreciou o evento em termos de divulgação?	32	32	0	0
Como apreciou o evento em termos de organização?	43	20	1	0
Como apreciou o evento em termos de conteúdo informacional?	42	21	1	0

Source: Research data (2024).

The high level of participant satisfaction is evident in their strong interest in deepening their knowledge of the STEAM approach. According to the graph below, 53 respondents expressed a desire to expand their knowledge of the topics presented at the event, while 11 indicated that they did not need to do so.

Graph 4 - Interest in delving deeper into the STEAM approach.



Source: Research data (2024).

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Regarding the questions: "Did the topics covered in the presentations contribute to the development of new knowledge that could support the planning of projects (learning or research) using a STEAM approach?" and "Did you know anything about the STEAM approach beforehand? If so, tell us how you learned about this approach and if you have experience with STEAM." The CSD technique (Lefèvre, F.; Lefèvre, A., 2005) was used to analyze the responses provided in the event evaluation questionnaire. The main steps of the CSD technique were followed: **Skimming the Speeches:** All participants' responses were read in general to familiarize themselves with the content; **Identification of Key Expressions (KEs)** : Underlying each response, phrases or excerpts that convey the essence of the respondent's idea were located, preserving the key expression; **Identification of Central Ideas (CIs)** : From the key expressions, short sentences were formulated that summarize the core of what is being said, creating a thematic category; **Grouping of Key Expressions by Central Idea:** All the CIs that correspond to the same CI were grouped, even if they came from different participants; **Construction of Collective Subject Discourses (CSDs)** : A single speech was written for each CI, using excerpts from the participants' own CIs, representing the collective; and, finally, **Presentation of Results:** The CSDs and the respective CIs were organized, presenting as an interpretative synthesis of the collected data.

This means that the participants' actual statements were preserved and transcribed for further analysis. This allowed us to tabulate and organize qualitative data. This enabled us to understand a group's thoughts, representations, beliefs, and values regarding the event's central themes.

Charts 3, 4, and 5 below present the CSDs originating from the question, "In your opinion, did the topics covered in the presentations contribute to the development of new knowledge that could support the planning of projects (learning or research) using a STEAM approach?" followed by their respective analyses. The same strategy is subsequently adopted for the question: "Did you already know anything about the STEAM approach? If yes, please describe how you learned about this approach and whether you have had any STEAM experiences." The CSDs for this question are demonstrated in Charts 6 and 7.

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Chart 3 - CSD - Contribution of the topics addressed in the development of new knowledge.

Yes, absolutely. A broader perspective and a more horizontal approach, along with the presented tools, will bring about change within my team. [...] It once again reinforced the importance of using technology in teaching. I just need to delve deeper into the topic. [...] I believe the STEAM approach can be used more frequently in educational practices. The topics reinforced my developing knowledge of STEAM areas and complemented the focus of my doctoral research on STEM at Universidade Aberta. [...] Without a doubt, good examples of STEAM-based projects and activities were presented, as well as the most suitable strategic actions and methodologies for this approach. The presentations covered enriching and inspiring topics, offering a broad view of the possibilities for implementing the STEAM approach in learning projects. These presentations were fundamental to developing new knowledge and perspectives that will certainly inform the planning of future projects. They contributed to the understanding that this theme is universal. The speakers were undoubtedly very relevant and provided interesting contributions to the STEAM approach. The topics gave me the tools to try the STEAM approach in my teaching practice [...] and in planning for future implementation. I believe the topics could contribute to developing new projects for sharing knowledge and developing 21st-century skills. The topics covered are a starting point, a call to attention to a STEAM approach, very important, especially for those who have not yet had contact or training in this area. The topics presented contributed to the development of new knowledge and also provided valuable tools and perspectives for planning STEAM projects. [...] new project ideas. Learning about the different projects carried out helps to see their applicability in the school context. Naturally, reporting on experiences and *projects* is always a source of information and knowledge to consider. It was a presentation of what can be done. The projects presented were a good explanation of how STEAM can work. [...] it allowed for a deeper approach to STEAM. The event primarily encourages reflection and strategy development within a STEAM framework. [...] It still requires incorporation into the curricular foundations. However, for project and/or lesson planning, there will need to be more specific training and/or independent research tailored to the skills to be developed and knowledge to be acquired.

Source: Research data (2024, translated and adapted by us).

The discourses presented in Chart 3 align with those raised in a study by Dias and Mello (2022). In that study, the researchers examined the potential contributions of the STEAM approach to developing competencies and skills in Natural Sciences, as outlined in Brazil's National Common Curricular Base (Brasil, 2018). The authors identified challenges related to engagement in educational processes, teacher training focused on school realities, solving real problems, and developing students' critical thinking skills and creativity.

The literature suggests strategies for integrating STEAM areas (Branco; Cavadas, 2023) and emphasizes enabling students' personal development and well-being by engaging them in meaningful STEAM-based learning activities that increase their interest and engagement (Correia et al., 2023). However, it is essential to consider the need for continuing education for teachers so they can acquire the necessary theoretical and practical knowledge to plan STEAM activities with their peers. Chart 4 presents a CSD that highlights the importance of the event for participants' academic and professional development.

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Chart 4 - CSD - Perception of the need for continuing education.

I'm happy the event took place; it helped me with my academic development. [...] Participating in the educators' experiences broadened my horizons. [...] Today, I understand that there's a vast universe outside the classroom that we must explore. At that moment, we realize our limitations as teachers and mediators of the educational process. [...] In my case, it served to broaden and consolidate actions, as the practical examples presented facilitated the process of assimilating new ideas. I'm excited to apply what I learned and continue exploring ways to promote a more integrated, creative, and meaningful education for students. [...] For me, it's still a nascent reality in the various topics covered. [...] I need more experience to apply it. I believe the hard work that remains must be done with the teachers who still rely on chalk, blackboard, and saliva. [...], but we still have a long way to go. [...], because it's very important as a teacher to always stay up-to-date and use new tools in innovative and motivating ways for students.

Source: Research data (2024, translated and adapted by us).

The discourse in chart 4 is corroborated by the arguments of Dos Santos, Silveira and Lavicza (2022), when they state that priority should be given to the adoption of contextualized approaches that contribute to meaningful learning, from an interdisciplinary perspective.

> Interdisciplinary teaching allows students to connect different areas of knowledge, fostering meaningful learning. It also encourages students to broaden their perspective on the events they experience in their lives, developing new approaches to the surrounding reality. This experimentation is crucial as students connect phenomena while being motivated by scientific and technological fields (Heck, 2017 *apud* Caldas; Machado, 2023, p. 292, translated by us).

In this sense, it becomes necessary to "look beyond the disciplines in order to build concepts that encompass different perspectives, and based on project work, this approach seeks to assign meaning to information and understand the sciences from a broad perspective that considers their multiple interactions (Lorenzin, 2020, p. 193, translated by us). Furthermore, according to Lorenzin (2020, p. 189, translated by us), it is "aiming to form subjects with a broad and contextualized view of phenomena, able to deal with a complex reality and with an interest in scientific knowledge, that the STEAM approach presents itself as a possible guidance for a new organization of teaching [...]".

To this end, the adoption of the STEAM approach must be based on implementing continuing teacher training programs that use innovative practices (Dos Santos; Silveira; Lavicza, 2022). In one of their studies, the authors mention an experience focused on "training teacher trainers and primary and secondary school mathematics teachers in the use of GeoGebra software in a STEAM context [...]" (Dos Santos; Silveira; Lavicza, 2022, p. 60, translated by us). Through this process, the authors aim to promote pedagogical practices that impact student learning by integrating the software into teacher training. GeoGebra's practices adopt more contextualized, meaningful, and creative approaches that favor achieving new knowledge and extrapolating mathematics.

Thus, as Dos Santos, Silveira, and Lavicza (2022) described, the event "IV Cycle of Training

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Pathways: Teacher Training in Times of STEAM Education," which is mentioned and analyzed in this article, through presentations by guest speakers, including researchers from Brazil and Portugal, participants learned about practices conceived within a STEAM approach with an emphasis on the following themes: "Educational Robotics: An Experience in a High School Integrated with Technical Education" and "Educational Robotics, Computational Thinking, and Innovation." Notably, Educational Robotics was present among the digital technologies highlighted in the presentations. This is because the research projects that guided the organization of this event focused on introducing Educational Robotics in the context of high school integrated with technical education from a STEAM perspective, as mentioned in the introduction. It is worth noting that this bias was expanded since other STEAM project-related themes were also covered, such as: "Creativity and Entrepreneurship in Academic Training with PBL and STEAM" and "Teacher Training and STEAM Projects with the Use of Technologies," among others, as shown in chart 1, previously made available.

The participants valued the thematic diversity, which was enriched by the presenters' and speakers' experience reports. They expressed that the event contributed to their academic development and broadened their horizons, as seen in the CSD excerpt presented in Chart 4: "I'm happy the event took place; it helped me with my academic development. [...] Participating in the educators' experiences broadened my horizons. [...] Today, I understand that there is a vast universe outside the classroom that we must explore." However, the same CSD acknowledges that there is still much to learn about the STEAM approach and that special attention should be given to teachers who limit themselves to traditional methods. "[...] For me, it's still an embryonic reality in the various topics covered. [...] I need more experience to apply it. I believe the necessary hard work must be done with teachers who still rely on chalk, a blackboard, and saliva. [...], but we still have a long way to go."

Furthermore, participants in the "Training Pathways Cycle" pointed out that proposals involving STEAM are beneficial to the teaching and learning process, since they approach the reality in which students are immersed, as noted in the CSD and shown in Chart 5:

Chart 5 - CSD - Perception of the application of STEAM in the teaching and learning process.

The discussion about including students as active participants in the teaching and learning process through interdisciplinary areas/topics that reflect the realities of society is of great value for the comprehensive development of students. In my opinion, the STEAM methodology offers two approaches to teaching and learning for current students and future generations.

Source: Research data (2024, translated and adapted by us).

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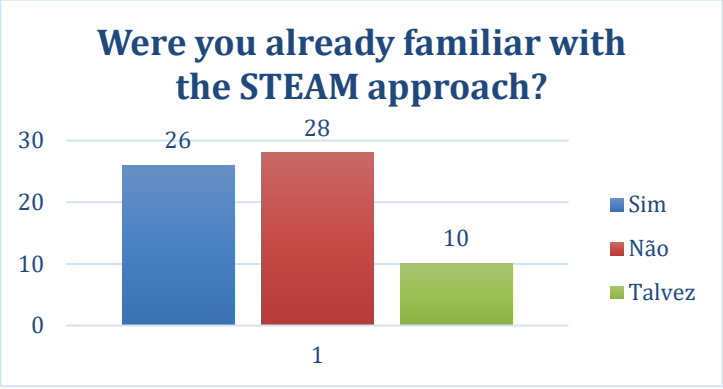
In the STEAM approach, students work on interdisciplinary projects that challenge them to find solutions to real-world problems. They alternate between individual and collaborative activities and get hands-on experience. By incorporating an active dimension into the learning process, the STEAM approach ensures that students are at the center of it, guided by the teacher as they construct new knowledge. This dynamic promotes cognitive, social, and attitudinal development, critical thinking, and creativity. It also fosters various socio-emotional skills. "The great challenge is to articulate academic knowledge, which should not be discarded, with broader skills and competencies that help students apply the knowledge they acquire in school to solve daily, current, and future challenges" (Garofalo; Bacich, 2020, p. 171–172, translated by us). To this end, the authors suggest connecting the school to the real world and articulating socio-emotional learning with the "formal" curriculum (Garofalo; Bacich, 2020, p. 172). Thus, STEAM-based teacher training helps students develop learning skills increasingly relevant to their context.

When asked the question: "Were you already familiar with the STEAM approach? If the answer is YES, please tell us how you learned about this approach and if you have had any STEAM experiences," the data revealed, according to Graph 5, that there was still some lack of knowledge regarding the use of this approach, especially among those already working in teaching. Proof of this is that almost half of the respondents were unfamiliar with the STEAM approach. This can be seen in the graph below and in the CSD available in Chart 6, immediately following:

Graph 5: Prior knowledge about the STEAM approach.



Source: Research data (2024).

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Chart 6 - CSD - Statements indicating lack of prior knowledge and experience in the STEAM approach.

Without prior knowledge...
No. I hadn't heard of it before. I'd never heard of the STEAM approach before. Only at this last event. [...] I wasn't familiar with it, but I found it quite positive. I've never had a complete experience, but rather individual initiatives associated with robotics and formal education. Sometimes I participate with students in interdisciplinary projects, but I've never participated in a project identified as STEAM. [...] it was a very educational class. I hadn't had any STEAM experience before.

Source: Research data (2024, translated and adapted by us).

The respondents' statements demonstrate how much research and training actions on STEAM education in all its possible aspects still need to be explored and developed.

> STEAM education represents a revolution in teaching, integrating science, technology, engineering, arts, and mathematics in a practical and interdisciplinary way. This approach not only enriches learning but also prepares students for challenges, developing skills such as critical thinking, creativity, collaboration, and complex problem-solving.
> By implementing STEAM Education, teachers can transform classrooms into dynamic spaces of inquiry and innovation, where students are encouraged to explore and apply knowledge meaningfully. Despite implementation challenges, effective strategies and appropriate support can overcome these difficulties, providing a more engaging and relevant education. (Education..., 2024, translated by us).

Respondents who indicated some prior knowledge of STEAM mentioned the need to invest in digital education training to enable the use of these new tools and provide an innovative, motivating classroom environment for students. Those who answered "yes" to the above question mentioned learning about this approach through professional training and graduate programs. However, they primarily learned about it through their own initiative or through the school where they worked, as shown in the excerpts from the statements included in the CSD in Chart 7.

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Chart 7 - CSD - Statements about prior knowledge and experiences in the STEAM approach.

With prior knowledge...
I learned about it... Through school. We applied it at school. Information was released by the School Administration. I read books about it, approached the research group, and applied it in the classroom. Self-study. Research. Investigation. Through Universidade Aberta of Portugal. Online training. I've read articles about it. At the University of Évora, in my undergraduate degree in GRH. I learned about it through reading and teacher training courses. I had this approach during my academic training, even though I had a different title at the time and it was still very much in the theoretical field. Through reading and research on education. I've already had STEAM experiences. Through conversations with professors at the Open University. I'm reading about the subject. Previous training. [...] research in this area. [...] through my own protean journey . I also learned about it in the postgraduate program in HRM at the University of Évora. I've dedicated myself to training and teaching for 40 years, always with a holistic and integral, cultural and humanizing perspective. [...] I use robots to create interdisciplinary projects. I have taught many webinars and training sessions, written chapters, and developed and presented material for video classes on Design. *Thinking ,* while I was an innovation agent at InovaCPS . This methodology encompasses project-based learning approaches, from immersion to prototyping and testing. As a manager of a basic education school, I've been involved with maker culture and in initial teacher training through an inED -ESE-IPP project. I learned about the STEAM approach during my Master's research, having already used it without knowing it had that name. My knowledge of STEAM is limited, considering my focus is primarily on STEM. However, I've had the opportunity to read some literature that supports the success of STEM, independent of an integrated relationship with the arts, social sciences, and humanities. I became interested in and researched STEM a few years ago. I've been implementing the STEAM approach in my teaching practice through interdisciplinary projects included in Domains of Curricular Autonomy, which have included STEM and non-STEAM subjects. I have also participated in several STEM trainings, the most recent being *"STEM Out of The Box: A STEM Approach to Non-STEM Subjects Rerun " of the European Schoolnet Academy* . I also participate in my school's Ciência Viva Club, where we run a weekly STEAM Lab. It's a topic that interests me greatly."

Source: Research data (2024, translated and adapted by us).

Similar results to those in Chart 6 were obtained by Caldas and Machado (2023). Their study shows that participants in STEAM training courses understood the approach and were interested in encouraging interdisciplinary activities and active student participation. The need for integrated approaches to skills development continually emerges, recognizing that competencies do not exist in isolation, but rather complement and reinforce each other in everyday, professional, and educational environments.

Because STEAM is a recent approach, it is still little disseminated in the formal educational environment. Reading the transcripts reveals that the actions or training to acquire knowledge of the STEAM approach mostly originate from the participants themselves. This depends on their interest in continuing education and their desire to acquire new knowledge and learn about technological advances and new methodologies and approaches.

In addition, some limitations of the study must be considered. Implementing the STEAM approach in teacher training in Brazil and in international contexts presents several limitations, both methodological and related to the generalizability of the results.

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In the field of methodology, it has been observed that most studies focus on specific regions of Brazil, primarily the Southeast and South, and particularly urban areas. This limits our understanding of the applicability of the STEAM approach in rural areas or less privileged regions (Maia; Carvalho; Appelt, 2021). Additionally, qualitative research designs are prevalent, often employing case studies with small sample sizes. This hinders replication of results and limits the scope of conclusions (Lasakowski, 2023). Additionally, there is a notable scarcity of longitudinal studies evaluating the long-term impact of STEAM-based teacher training, which hinders the analysis of this methodology's continued effectiveness (Munhoz; Gonçalves; Mello, 2024). Additionally, many teachers demonstrate a lack of knowledge or limited understanding of the approach, hindering practical implementation and the full utilization of STEAM's potential (Munhoz; Gonçalves; Mello, 2024).

In terms of limitations in generalizing the results, it's important to note that many studies focus on secondary education, with limited representation of other stages of basic education, such as elementary school and early childhood education. This prevents a broader view of the applicability of the STEAM approach across the entire educational system (Vasconcelos, 2023). Additionally, the absence of specific and comprehensive public policies promoting STEAM-focused teacher training hinders the expansion and consolidation of this practice in the Brazilian educational system (Vasconcelos, 2023).

Regarding the challenges related to internationalization, it is important to highlight the scarcity of comparative studies between Brazil and other countries. This limits our understanding of successful practices abroad and how they can be adapted to local contexts (Milara; Orduña, 2024).

To overcome these limitations, the geographic scope of research must be broadened to encompass greater regional and socioeconomic diversity. Additionally, there must be investment in longitudinal studies to assess the medium- and long-term effects of STEAM-based teacher training. It is also necessary to develop public policies that promote ongoing teacher training within this interdisciplinary perspective, as well as to intensify international collaborations to share best practices and effective methodologies adaptable to diverse educational realities.

FINAL CONSIDERATIONS

This article highlighted participants' perceptions of the STEAM approach in continuing teacher education, as discussed at the online event "IV Cycle of Training Pathways," held in April

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2024. The results indicate that most participants, both Brazilian and Portuguese, were unfamiliar with the approach but expressed great interest in learning more after the event. Those with prior STEAM experience reinforced the importance of interdisciplinary activities and greater student engagement.

Data analysis revealed that participants found the presented topics enriching and inspiring. The event provided a broader understanding of the STEAM concept, with robotics, physics, and science in general standing out as the most interesting areas.

Furthermore, the need for ongoing training was consistent in the responses, indicating that events like this one are essential for updating teachers and introducing new educational methodologies in schools. Participants recognized the importance of staying up to date and using innovative tools that promote a more integrated, creative, and meaningful education.

This article is based on data analyzed using the CSD technique. It demonstrates that collaborative exchanges between participants prove the pedagogical internationalization of education to be an essential tool for promoting multinationalization of teaching, especially in digital contexts. Advantages include expanded access to collective knowledge, promotion of multicultural education, and understanding the fundamentals and principles of the event's themes. However, challenges remain, including the need for adequate technological infrastructure, teacher training for digital environments, and ensuring equitable access to education. Implementing this proposal effectively requires striking a careful balance between innovation and inclusion to maximize the benefits and mitigate the difficulties inherent in the process.

There is a wealth of opportunities to advance research and training sessions regarding the STEAM approach. This is clearly and perceptibly reflected in the experience gained during the event and the analysis of the data collected. Internationalization has demonstrated the importance of overcoming physical barriers and understanding how different locations address the same issues. With the advent of ICTs, boundaries to accessing knowledge should no longer exist. Reflecting on this, it becomes essential to consider "a new cartography of learning" (Farias, 2023, p. 62, translated by us).

Undoubtedly, the connection between STEAM, teacher training, and internationalization presents a complex contemporary challenge in education. Integrating these dimensions requires updating teacher training curricula and profoundly reviewing traditional pedagogical practices, which often remain anchored in fragmented disciplinary paradigms.

The STEAM approach integrates the fields of science, technology, engineering, arts, and mathematics. It challenges teachers to develop competencies that go beyond their initial training areas. However, teacher training in many Brazilian contexts still does not effectively address the

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competencies required for interdisciplinary, creative, technological pedagogical practice. This issue is further complicated by the difficulty of institutionalizing internationalization practices in teacher training, especially given the existence of language, economic, and educational infrastructure barriers.

In light of these challenges, devising effective ways to integrate STEAM, teacher training, and internationalization is crucial. Initial and continuing teacher training must be strengthened so that teachers can develop skills for working in interdisciplinary and globalized pedagogical contexts. Continuing education programs that emphasize interdisciplinarity, digital literacy, innovation, and participation in international academic collaboration networks are promising strategies in this regard.

Furthermore, creating public policies that encourage incorporating the STEAM approach into school curricula, along with academic mobility programs and international cooperation projects, can help bridge the existing gap between these concepts. The internationalization of teacher training, understood not only as the implementation of physical exchanges but also as the establishment of partnerships and joint projects in virtual environments, offers concrete possibilities for expanding educational horizons and strengthening innovative pedagogical practices.

Another relevant avenue is investing in academic research that critically analyzes the application of STEAM in different educational contexts. Studies that consider cultural, regional, and socioeconomic specificities can generate evidence of adaptable, sustainable best practices. This type of knowledge production is essential for consolidating the adoption of STEAM and teacher training focused on internationalization in a critical and contextualized manner.

Therefore, expanding and integrating these concepts into the field of education requires a systemic and collaborative approach involving universities, schools, government agencies, and international organizations. Only through coordinated, sustainable action can the identified challenges be transformed into opportunities for pedagogical innovation and strengthening 21st-century education.

In summary, future training initiatives must continue to explore these topics in depth, as these approaches are constantly evolving. Nevertheless, the IV Cycle of Training Pathways achieved its objectives by providing a forum for international exchange of STEAM-related experiences and knowledge between Portugal and Brazil, contributing to the professional development of educators and teachers across various levels and encouraging practical application of the discussed concepts.

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