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SCIENCE POPULARIZATION AS A PEDAGOGICAL STRATEGY FOR FOOD SECURITY, BIODIVERSITY AND SOCIOTERRITORIAL INCLUSION IN THE STATE OF RIO DE JANEIRO

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ABSTRACT

Objective: This study analyzes the popularization of science as a pedagogical strategy for food security, biodiversity, and socioterritorial inclusion in traditional and vulnerable communities of the state of Rio de Janeiro, Brazil.

Theoretical Framework: Grounded in the pedagogy of Paulo Freire, the agroecology of Miguel Altieri, and the concept of development as freedom by Amartya Sen, the framework articulates ethnoscience, food sovereignty, the ecology of knowledges of Boaventura de Sousa Santos, and the critical environmental education of Isabel Cristina de Moura Carvalho, fostering social technologies.

Method: A qualitative and participatory methodology was employed, including diagnosis, workshops, and practical activities. The initiative involved quilombola communities, artisanal fishers, women artisans' groups, and vulnerable urban residents. Data were collected through observation and discussion circles.

Results and Discussion: Strengthening of community autonomy, improvements in food security, and sustainable income generation were observed. Technologies such as micro-sprinkler irrigation optimized water use and supported learning. The discussion validates the pedagogical approach and its social impact.

Research Implications: Practical implications highlight pathways for inclusion, income generation, and quality of life. Theoretically, the study validates the integration of knowledge for critical environmental education and territorial development.

Originality/Value: This research innovates by integrating science popularization, social technologies, and participatory pedagogies to foster community empowerment. It demonstrates the role of science in promoting sustainable practices that are replicable and capable of driving social transformations in vulnerable territories.

Keywords: Science Popularization, Agroecology, Social Technologies, Food Security, Socioterritorial Inclusion.

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POPULARIZAÇÃO DA CIÊNCIA COMO ESTRATÉGIA PEDAGÓGICA PARA A SEGURANÇA ALIMENTAR, BIODIVERSIDADE E INCLUSÃO SOCIOTERRITORIAL NO ESTADO DO RIO DE JANEIRO

RESUMO

Objetivo: Este estudo analisa a popularização da ciência como estratégia pedagógica para segurança alimentar, biodiversidade e inclusão socioterritorial em comunidades tradicionais e vulneráveis do Estado do Rio de Janeiro.

Referencial Teórico: Ancorado na pedagogia de Paulo Freire, na agroecologia de Miguel Altieri e no desenvolvimento como liberdade de Amartya Sen, o referencial articula etnociência, soberania alimentar, ecologia de saberes de Boaventura de Sousa Santos e educação ambiental crítica de Isabel Cristina de Moura Carvalho, promovendo tecnologias sociais.

Método: Metodologia qualitativa e participativa, com diagnóstico, oficinas e práticas. Envolveu comunidades quilombolas, pescadores artesanais, grupos de mulheres artesãs e moradores vulneráveis fluminenses. Dados coletados por observação e rodas de conversa.

Resultados e Discussão: Fortalecimento da autonomia comunitária, melhoria da segurança alimentar e geração de renda sustentável foram observados. Tecnologias como microaspersão otimizaram uso da água e aprendizado. A discussão valida a abordagem pedagógica e seu impacto social.

Implicações da Pesquisa: As implicações práticas apontam caminhos para inclusão, geração de renda e qualidade de vida. Teoricamente, validam a integração de saberes para educação ambiental crítica e desenvolvimento territorial.

Originalidade/Valor: A pesquisa inova ao integrar popularização da ciência, tecnologias sociais e pedagogias participativas para empoderamento comunitário. Demonstra o papel da ciência na promoção de práticas sustentáveis replicáveis e transformações sociais em territórios vulneráveis.

Palavras-chave: Popularização da Ciência, Agroecologia, Tecnologias Sociais, Segurança Alimentar, Inclusão Socioterritorial.

POPULARIZACIÓN DE LA CIENCIA COMO ESTRATEGIA PEDAGÓGICA PARA LA SEGURIDAD ALIMENTARIA, LA BIODIVERSIDAD Y LA INCLUSIÓN SOCIOTERRITORIAL EN EL ESTADO DE RÍO DE JANEIRO

RESUMEN

Objetivo: Este estudio analiza la popularización de la ciencia como estrategia pedagógica para la seguridad alimentaria, la biodiversidad y la inclusión socioterritorial en comunidades tradicionales y vulnerables del estado de Río de Janeiro, Brasil.

Marco Teórico: Basado en la pedagogía de Paulo Freire, la agroecología de Miguel Altieri y el concepto de desarrollo como libertad de Amartya Sen, el marco articula etnociencia, soberanía alimentaria, ecología de saberes de Boaventura de Sousa Santos y educación ambiental crítica de Isabel Cristina de Moura Carvalho, promoviendo tecnologías sociales.

Método: Se adoptó una metodología cualitativa y participativa, con diagnóstico, talleres y prácticas. La experiencia involucró comunidades quilombolas, pescadores artesanales, grupos de mujeres artesanas y residentes urbanos en situación de vulnerabilidad. Los datos se recopilaron mediante observación y círculos de diálogo.

Resultados y Discusión: Se observó el fortalecimiento de la autonomía comunitaria, mejoras en la seguridad alimentaria y generación de ingresos sostenibles. Tecnologías como la microaspersión optimizaron el uso del agua y favorecieron el aprendizaje. La discusión valida el enfoque pedagógico y su impacto social.

Implicaciones de la Investigación: Las implicaciones prácticas señalan caminos para la inclusión, la generación de ingresos y la calidad de vida. Teóricamente, el estudio valida la integración de saberes para la educación ambiental crítica y el desarrollo territorial.

Originalidad/Valor: La investigación innova al integrar popularización de la ciencia, tecnologías sociales y pedagogías participativas para el empoderamiento comunitario. Demuestra el papel de la ciencia en la promoción de prácticas sostenibles replicables y en la generación de transformaciones sociales en territorios vulnerables.

Palabras clave: Popularización de la Ciencia, Agroecología, Tecnologías Sociales, Seguridad Alimentaria, Inclusión Socioterritorial.

1 INTRODUCTION

The popularization of science, understood as situated social practice, demands dialogical processes of knowledge production that recognize local knowledge as legitimate and necessary. This perspective is in line with Freire's pedagogy, which understands that "no one educates anyone, no one educates himself, men educate each other, mediatized by the world" (FREIRE, 1974). Thus, science ceases to be imposed in a vertical way and starts to be built collectively with communities, in a movement of listening and dialog.

Brandão (1981) points out that education is not limited to school, but is expressed in multiple social and cultural spaces, and it is essential that the teaching-learning processes consider the practices and experiences of traditional and peripheral populations. In the same direction, Carvalho (2012a) defends a critical environmental education, guided by an emancipatory political-pedagogical project, in which the subjects are able to interpret and transform their reality. In addressing the formation of the ecological subject, Carvalho (2012b) reinforces that the construction of environmental awareness is inseparable from educational practice and citizen participation.

The pedagogical proposal of Gadotti (2000) contributes by emphasizing sustainability as an integrating axis of the curriculum, pointing to the need to connect education and care with the environment. In this sense, the practice of popularization of science is articulated with the construction of a socio-environmental citizenship, which recognizes the centrality of nature in educational processes. Guimarães (2004) complements this view by highlighting that the environmental crisis requires transdisciplinary responses, in which education is able to promote a complex understanding of the world.

As Leff (2001, p. 23) argues, "environmental knowledge is based on the articulation of different rationalities, opening new paths for critical thinking and sustainable practices." This conception reinforces the idea that the democratization of science must be associated with the

recognition of multiple forms of knowledge. In this horizon, Lorenzetti & Delizoicov (2001) argue that science, when worked in basic education, should favor the critical formation of students, allowing them to understand the social role of scientific knowledge.

The dialog between science, culture and environment is also anchored in the reflections of Reigota (2001), who understands environmental education as a political practice aimed at social transformation and the construction of new ethical values. This perspective is deepened by Santos (2006a), when criticizing the indolent reason that despises daily experiences and, therefore, wastes fundamental knowledge for the construction of knowledge. In continuity, Santos (2006b) proposes a new grammar of time, in which social practices are understood in their historicity and transformative potential.

Thus, the popularization of science, especially in quilombola and peripheral communities, cannot be understood only as content transmission, but as a dialogical, emancipatory and critical practice, based on references that integrate education, sustainability and social justice. It is on this theoretical basis that the actions presented here are anchored, which value active listening, collective construction and respect for the diversity of knowledge, in line with the guidelines of critical environmental education (FREIRE, 1974; CARVALHO, 2012a; REIGOTA, 2001).

2 THEORETICAL FRAMEWORK

This study is based on a set of theoretical references that, in dialog with each other, support the actions developed.

Among the conceptual pillars, popular education constitutes a structuring axis to understand science as a social and transformative practice. In this perspective, the educational process should be dialogical, participatory and non-invasive, recognizing communities as protagonists of their own learning. As Freire (1987, 1996) argues, knowledge is collectively produced, mediated by concrete reality and social practice. Brandão (1981) and Gadotti (2000) reinforce this conception by situating popular education as praxis focused on human emancipation and critical participation. More recently, Haddad and Di Pierro (2021) and Pini (2011) updated the debate, highlighting participatory methodologies and the importance of active listening as a condition for democratic educational processes.In the field of agroecology, Altieri (2009, 2018) highlights sustainable agriculture as a practice that integrates environmental, social and economic dimensions, breaking with conventional models of agricultural exploitation. Caporal and Costabeber (2019) and Pacheco (2021) expand this

discussion by associating agroecology with the promotion of social justice and community strengthening. The debate on food sovereignty and security (Moreira, 2015; Pacheco, 2017) emphasizes the right of populations to define their own production and consumption strategies. This perspective is aligned with the Sustainable Development Goals (UN, 2015), especially those dealing with the eradication of hunger, health, quality education, reduction of inequalities and promotion of environmental sustainability.

The popularization and dissemination of science are configured as another theoretical pillar. More than translating scientific content for different audiences, it is about building mediation processes that respect cultural contexts, traditional knowledge and territorial specificities. In this sense, Diegues (2000) and Carneiro da Cunha e Almeida (2009) defend the valorization of traditional knowledge as part of the collective heritage. In Brazil, initiatives such as the Embrapa & Escola program and the National Week of Science and Technology have demonstrated the potential of extra-murals actions to bring science, schools and communities closer together (Embrapa, 2024). In addition, Castells (2010) and Jenkins (2006) help to understand how the network society and the culture of convergence reconfigure the forms of circulation and appropriation of scientific knowledge, expanding learning spaces.

The social technologies applied to the educational context strengthen the articulation between science and daily life. Inspired by Freire (1987) and active methodologies approaches (De Sousa, Azevedo & Alves, 2021; Pereira et al., 2018), such experiences allow concrete practices — such as urban gardens, micro-sprinklers, sensory gardens or the production of biojewelry from fish waste — to be incorporated into the pedagogical process. These initiatives contribute to sustainability, social innovation and the collective construction of knowledge, in dialog with the perspective of Sevilla Guzmán (2003).

As illustrated in Figure 1, the pedagogical actions developed integrate conversation circles, community gardens, school practices and applied social technologies, evidencing the participatory and interdisciplinary character of the proposal.

Figure 1

Popular activities and popular education. Conversation circle, community garden workshop, school activity and microsprinkler system with students, held in partner communities.

A – Planting in an agroecological urban garden in the municipality of Magé by students of the last year of high school.
B – Delivery of certificates to young people and adults participating in the workshops held in São Pedro da Aldeia.
C – Presentation of a prototype of an urban school garden with automation, developed by students of the 8th and 9th grade of Elementary School II, at E.M. GET Alzira Araújo, Rio de Janeiro / RJ.
D – Non-invasive participatory diagnosis with the Quilombo community of Santa Rita do Bracuí, Angra dos Reis/RJ.

Thus, the theoretical framework that guides this study combines foundations of popular education, agroecology, the popularization of science and social technologies, establishing a conceptual framework consistent with the principles of inclusion, participation and sustainability that guide the research.

3 METHODOLOGY

The research adopted a qualitative approach, with a participatory and non-invasive character, based on the references of popular education (Freire, 1996; Brandão, 1981; Gadotti, 2000). The central methodological principle was the recognition and appreciation of local knowledge, leading educational processes guided by active listening, collective construction and community autonomy. All actions were guided by the principles of agroecology, understood as a scientific, practical and cultural basis for the promotion of food sovereignty, environmental preservation and the strengthening of territorial identity.

3.1 SELECTION OF TERRITORIES

The definition of the territories of action contemplated quilombola communities, public schools, urban communities in situations of social vulnerability, family farmers and artisanal fishermen's colonies in the state of Rio de Janeiro. The selection was based on official social indicators (TABLE 1), such as the Social Vulnerability Index (SVI), the Municipal Human Development Index (MHDI) and the Gini Index (Institute of Applied Economic Research [IPEA], 2010; United Nations Development Program [UNDP], Institute of Applied Economic Research [IPEA], & João Pinheiro Foundation [FJP], 2013; Brazilian Institute of Geography and Statistics [IBGE], 2010), which showed pockets of inequality and food insecurity in municipalities with different levels of human development.

Table 1

Human development indexes, social vulnerability and income inequality in the territories of action

Município	IDHM (2010)[1]	IVS (2010)[2]	Índice de Gini (2010)[1]
Angra dos Reis	0,714	Médio	0,547
Cachoeiras de Macacu	0,701	Alto	0,556
Magé	0,709	Alto	0,561
Mangaratiba	0,753	Médio	0,544
Rio Claro	0,683	Alto	0,558
Rio de Janeiro	0,799	Médio	0,54
São Pedro da Aldeia	0,712	Médio	0,541
Seropédica	0,713	Médio	0,552
Valença	0,73	Médio	0,549

Source: [1]IBGE (2010); [2]IPEA (2010)

This analysis revealed significant contrasts between central urban areas and peripheral or traditional communities, reinforcing the need for educational actions aimed at reducing vulnerabilities. The definition of the territories of action considered social indicators, such as the Municipal Human Development Index (IDHM), the Social Vulnerability Index (IVS) and the Gini Index, which show structural inequalities and fragilities in the supply of basic services (IPEA, 2010; UNDP, IPEA, & FJP, 2013; IBGE, 2010). In the case of the Lakes Region, the choice of the municipalities of Araruama, Cabo Frio, Iguaba Grande, São Pedro da Aldeia and Arraial do Cabo is also justified by the environmental and sociocultural relevance of the Araruama Lagoon, recognized as the largest permanent hypersaline lagoon in Latin America, with approximately 220 km² and average salinity between 50 and 60‰ (Silva; Costa; Martins, 2018). This unique ecosystem suffers significant anthropogenic pressures, including wastewater discharge with insufficient treatment, disorderly urban occupation and eutrophication processes, which compromise water quality and the sustainability of artisanal fisheries (Diegues, 2000; Costa; Fiszon, 2016). The integration of these socioeconomic and ecological criteria underlies the need for educational and participatory interventions, strengthening sustainable management practices, valuing local knowledge and expanding

socio-environmental awareness in strategic territories for the conservation of biodiversity and the maintenance of traditional fishing activity.

3.2 METHODOLOGICAL PROCEDURES

The actions carried out in the territories prioritized the integration between science, culture and local food production practices. In Magé, lectures and workshops on agroecological practices were conducted in urban gardens, involving students from different districts, including from communities in situations of social vulnerability.

In Angra dos Reis, in Quilombo Santa Rita do Bracuí, besides the valorization of the agro-industrialization of juçara pulp, there were participatory workshops of recognition of medicinal plants of the Atlantic Forest, conducted with the collaboration of specialists and mediated by listening to griots (guardian and transmitter of memory and ancestral knowledge of the community), which shared ancestral uses. A workshop was also promoted focused on the recognition and ecological and cultural importance of meliponas (stingless bees), highlighting their role in environmental conservation and quilombola identity.

In Mangaratiba, the activities in Quilombos Santa Justina, Santa Isabel and Ilha da Marambaia reinforced the importance of productive backyards, encouraging the diversified cultivation of vegetables, fruit and medicinal plants as a way of subsistence and cultural appreciation.

In Rio Claro, in Quilombo Alto da Serra, participatory diagnoses were carried out that subsidized workshops aimed at strengthening agroecological production and local identity.

In the capital, Rio de Janeiro, in public schools and vulnerable communities, school and vertical gardens, healthy eating workshops, and micro-sprinkler irrigation systems have been developed. In these spaces, the students were protagonists in the development of automation prototypes of irrigation, integrating temperature and humidity sensors, solar energy and climate monitoring software, as well as computerized systems to assist in the management of the school cafeteria, promoting the rational use of food.

In Seropédica, family farmers were encouraged to adopt agroecological practices for organic food production, while in Cachoeiras de Macacu sustainable cocoa production was stimulated. At Quilombo São José da Serra, in Valença, the work focused on qualifying the production of free-range eggs, with the formation of multiplier agents for the dissemination of organic and safe management practices.

Finally, in the colonies of artisanal fishermen of São Pedro da Aldeia and neighboring municipalities (Arraial do Cabo, Iguaba Grande, Cabo Frio and Araruama), workshops were developed to rescue artisanal fishing and naval carpentry, associated with the production of handicrafts from reused materials. In these localities, women's groups were supported in the production of biojewelry from fish waste, strengthening female protagonism and encouraging associations as a strategy for generating income and cultural valorization.

3.3 PEDAGOGICAL APPROACH

All actions were conceived based on active methodologies, favoring community listening and the integration between scientific knowledge and traditional knowledge. Agroecology was the articulating axis, offering theoretical and practical principles for the promotion of socio-environmental sustainability.

Another methodological pillar was the popularization of food science, translated into didactic and participatory activities that took concepts of Chemistry and Food Technology into the territories. These practices allowed participants of different ages to have direct contact, often for the first time, with scientific experiments applied to the food universe. In an elucidative and accessible way, the importance of science in the understanding of food, food safety and improving the quality of life was demonstrated, bringing academic research closer to daily experiences.

In each territory, we sought to train multiplier agents — among young people, women, teachers and community leaders — as a way to ensure the continuity of practices and local autonomy. The dialog between science and traditional knowledge was the central axis, consolidating the proposal that science can and should be experienced in dialog with the territories and their cultures.

4 RESULTSS AND DISCUSSÕES

The actions carried out showed substantial advances in the articulation between science, culture and territory, confirming the relevance of participatory, dialogical and non-invasive methodologies for the popularization of science in quilombola, fishing and peripheral contexts. The high adhesion to the thematic workshops, conversation circles and cultural valorization activities resulted in continuous engagement of young people and adults, highlighting the role of female associations focused on entrepreneurship, while all participants had access to

technical training articulated to identity practices - from the rescue of culinary knowledge and integral use of food to the recognition of edible mushrooms and the implementation of vertical gardens. In this process, it was observed the revaluation of local practices and the opening of concrete opportunities for income generation, with positive effects on self-esteem, social cohesion and organizational autonomy. In fishing territories around the Araruama Lagoon, for example, the discussion about adding value to local products and the rescue of artisanal fishing contributed to reframe traditional knowledge, producing shared meanings between science and culture. In urban areas marked by socioeconomic vulnerabilities, such as Pedra de Guaratiba and Santo Aleixo (Magé), active listening and the co-construction of community solutions proved to be an important way to align technical-scientific content with the concrete demands of the groups served, avoiding the imposition of external agendas and reinforcing situated learning processes.

In the school context, the results obtained by the students of the 8th and 9th years of Elementary School II of the Municipal School GET Alzira Araújo stand out, who, from the activities in the didactic garden, advanced from conceptual understanding to technological innovation. The students developed a prototype automation of the microsprinkler system powered by solar energy and rechargeable batteries, integrating humidity, temperature and rain sensors capable of automatically activating and interrupting irrigation according to local climatic conditions. The system communicates via Bluetooth to transmit data and issue alerts on the state of operation (on / off), being managed by software developed by the students themselves, which adjusts the rational use of water based on environmental readings and the water need of the site. At the same time, the group developed a mechanism for counting users of the school cafeteria (students and teachers), supporting the management in the adequacy of the acquisition and preparation of meals to the real number of daily visits, which contributed to reduce food waste and optimize the use of resources for school feeding. These initiatives, triggered by direct contact with science in concrete teaching and learning situations, consolidated logical reasoning skills, critical thinking and collaborative work, while materializing the principle of interdisciplinarity between Mathematics, Science and Social Technologies.

The interpretation of the results was anchored in the triangulation between primary data (field records, open interviews, participant observations) and secondary indicators (IDHM, IVS and Gini). This analytical procedure identified intra-urban and intra-municipal inequalities not captured by the statistical means, justifying the territorialization of actions and the adoption of differentiated intervention strategies. In municipalities with high MHDI, but with pockets of

poverty and food insecurity, the activities showed relevance and effectiveness by anchoring technical training in local demands; in areas with more acute deficits in infrastructure and public services, the focus was on low-cost technologies, community organization and training of multipliers. In both cases, the results corroborate that the popularization of science, when carried out through dialogical processes and recognition of knowledge, expands access to knowledge and strengthens local capacities to face socio-environmental challenges.

The observed effects are in strong convergence with the 2030 Agenda, notably with SDGs 2 (Zero Hunger and Sustainable Agriculture), 3 (Health and Wellness), 4 (Quality Education), 8 (Decent Work and Economic Growth), 10 (Reducing Inequalities), 12 (Responsible Consumption and Production), 14 (Life in Water) and 15 (Terrestrial Life). The incorporation of social technologies (such as automated microspraying guided by sensors and software) and practices of agroecological sciences and food science and technology (vertical gardens, full use of food and sustainable use of biodiversity) proved to be particularly effective in translating sustainability principles into daily procedures, generating multiplier effects through the performance of teachers, young people and local leaders. In addition, the results achieved in the workshops were amplified by the dissemination on social networks, through institutional pages and profiles of partners and co-executors, reaching thousands of views and interactions. Only on Instagram of one of the responsible researchers, more than 3,000 insights were registered, significantly increasing the visibility of the actions and stimulating the interest of new audiences for the dialog between science, culture and territory (data observed by the author). In the formative level, the integration between scientific contents and cultural repertoires has contributed to shift the popularization of science from a logic of transfer to an educational praxis that recognizes, legitimizes and enhances existing knowledge, fostering autonomy, belonging and social innovation in the territories.

In summary, the results show that the combination of participatory methodologies, appreciation of traditional knowledge and application of low-cost social technologies produces convergent gains in three dimensions: (i) socio-educational, meaningful learning and the formation of multipliers agents; (ii) socioeconomic, the rationalization of inputs, waste reduction and opening routes for adding value; and (iii) socio-environmental, sustainable management of resources and the conservation of local biodiversity. By inscribing these gains in community and school dynamics, the set of actions discussed here shows a promising way to reduce inequalities, strengthen institutional capacities and translate science into a tangible public good, with the potential for replicability in analogous contexts.

5 CONCLUSION

The actions developed showed that the popularization of science, based on participatory and non-invasive methodologies, was configured as a significant pedagogical practice for the strengthening of the relations between science, culture and territory. The experience with traditional, peripheral and school communities showed that the dialog between local and scientific knowledge not only expands the social relevance of knowledge, but also promotes contextualized and emancipatory formative processes.

Thematic workshops, conversation circles, urban gardens and cultural valorization activities were consolidated as significant learning spaces, in which children, young people, women and community leaders acted as protagonists of the educational process. This dynamic reinforced the centrality of dialog between different knowledge and interdisciplinarity as pillars for critical pedagogical practices, capable of transforming concrete social and environmental realities.

The results achieved showed advances in the training of multipliers, in the promotion of food security, in the valorization of biodiversity and in the stimulation of sustainable entrepreneurship. In addition, they showed the pedagogical potential of applied social technologies, especially when integrated into the teaching of Science and Mathematics in school contexts.

These impacts, in articulation with the Sustainable Development Goals of the 2030 Agenda, confirm the relevance of initiatives that associate the popularization of science, popular education and social technologies as instruments of socio-territorial inclusion and critical citizen formation. The pedagogical character of these actions transcends the moment of the intervention, projecting itself in the strengthening of the communitarian autonomy and in the replicability in other territories, respecting, in all the cases, its cultural and environmental specificities.

In this sense, the reported experience reaffirms that the popularization of science, when conceived as a dialogical and contextualized educational practice, contributes decisively to the democratization of knowledge, to the consolidation of transformative pedagogical practices and to the construction of an inclusive, sustainable and plural society.

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