



Transdisciplinarity is crucial to reformulate a sustainable future for the Amazon

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ABSTRACT

The Amazon, with its multidimensional nature, diverse in organisms, cultures and in its biophysical aspects, plays a prominent role in regulating the climate and providing ecosystem services essential to life on Earth. Its complex nature leads to equally complex problems in the human-nature interface, bringing forth the urgency of promoting transdisciplinary discussions to create innovative, equitable, fair and sustainable solutions. Here, we present the opinion of professionals from academia, companies, funding agencies, non-governmental organizations, civil society and government, from different areas of knowledge (environmental, social, biological and health sciences) on how to perform an inclusive and transdisciplinary science with the objective of finding solutions for the sustainability and conservation of the Amazon. We applied a semi-structured questionnaire with five complementary discursive questions aiming to synthesize the multiple visions for the application of transdisciplinary science in the Amazonian context. Scientist training, appreciation of traditional knowledge, broader spaces and time for promoting knowledge integration and co-creation of policies involving multiple actors were identified both as the main bottlenecks and the main solutions for transdisciplinary science in the academic environment and in policy decision-making. Most interviewees had already gone through transdisciplinary experiences during their education, indicating that initiatives to promote and implement transdisciplinarity exist elsewhere. However, we emphasize that greater coordination is needed between large research groups and funding agencies so that these experiences can be linked to a long-term transformative process, essential for the consolidation of transdisciplinary practices across various sectors of society.

Keywords: Amazon, transdisciplinarity, conservation, sustainable solutions, social inclusion.

Introduction

Transdisciplinarity integrates different fields of knowledge to solve complex problems that go beyond individual disciplines (Nicolescu, 2014). This approach is important for addressing global challenges such as human impact on the climate (IPCC 2022), overexploitation of natural resources (Pörtner, *et al.* 2021), social inequality (Scherhauser, 2021), utilization of ecosystem services (Geerts 2008) and socio-ecological resilience (Folke *et al.* 2016). By recognizing that complex issues cannot be solved through a single discipline or perspective, transdisciplinarity is necessary for discussions on sustainability and development at multiple scales, issues that require the integration of different perspectives towards common goals.

The Amazon is a region of 7 million square kilometers that spans nine countries, characterized by a rich diversity of flora, fauna, indigenous communities, and ancestral knowledge. It is home to millions of plant and animal species, many of which are still unknown to science, as well as over 3,300 indigenous and traditional communities with diverse cultural, linguistic, and ancestral knowledge on the use of natural resources (Raisg, 2023). However, the region faces challenges such as environmental degradation, deforestation, mining, illegal mining, land grabbing, and illegal exploitation of natural resources. These human activities have had negative impacts on the region's biodiversity and the livelihoods of communities that depend directly on it (Lapola *et al.* 2023). On the other hand, the Amazon also presents unique potential for sustainable solutions to the human-nature relationship, playing a crucial role in providing ecosystem services such as climate regulation, water provision, pollination, carbon sequestration, soil protection, and the prospecting of products such as medicines, timber, food, and high-value natural ingredients (Costanza *et al.* 1997; Levis *et al.* 2020). It is therefore important to think multidimensionally about the use of the region's resources and sustainable practices that respect the rights of communities and the forest's support capacity.

Transdisciplinarity can be a catalytic approach in addressing the complex problems of the Amazon, integrating different systems of knowledge and epistemologies that have been overlooked due to the colonial stance of hegemonic perspectives in Latin America (Taylor 2012). However, the application of a transdisciplinary approach faces numerous challenges, including linguistic differences, perspectives, and methodologies, disciplinary hierarchy, and difficulties in securing financial resources for transdisciplinary research. Additionally, the lack of coordination and resistance to change also need to be addressed. To

overcome these potential obstacles, it is important to adopt a collaborative and open approach, encourage communication and mutual understanding, have effective leadership and coordination processes, and be open to experimenting with new approaches and ideas (Jahn and Keil 2015).

Considering the need to create spaces for the discussion of multifaceted and interconnected issues, the São Paulo Research Foundation (FAPESP) organized the São Paulo School of Advanced Science on Sustainable and Inclusive Amazon (SPSAS Amazon) with the aim of promoting the advancement of science and technology for the benefit of the Amazon, with a focus on sustainability and social inclusion. Professionals from diverse fields gathered in São Pedro, São Paulo, between November 21 and December 5 2022, to discuss, collaborate, and integrate knowledge to solve issues in the Amazon. The interaction between disciplines and a holistic approach were extensively discussed in the first module of the course, with the goal of understanding the multifaceted phenomena of the region. This discussion aimed to level, inspire, and immerse participants/professionals in relevant concepts and discussions. In line with this, the objective of this article is to bring together the experiences and proposals of the course participants to promote knowledge related to Amazon sustainability. Through a specific questionnaire, researchers identified bottlenecks, proposed solutions, and shared experiences of transdisciplinary research. The raised issues aim to guide future initiatives in the construction of an inclusive science capable of integrating knowledge from different academic disciplines and other sectors of civil society in the formulation of public policies for the co-creation of alternatives for the conservation and sustainability of the Amazon.

Material and Methods

In order to facilitate a detailed investigation into how science can be conducted in a transdisciplinary and inclusive manner in the Amazon, we administered a questionnaire to professionals from various specialties, nationalities, genders, institutions, and fields of activity working in the Amazon. Data were collected during the São Paulo School of Advanced Science in the Sustainable and Inclusive Amazon (SPSAS), which took place from November 21 to December 5 2022. A total of 93 participants, including researchers from Biological and Agricultural Sciences, Social and Exact Sciences, as well as professionals from non-governmental organizations and private sector were invited to fill-up a semi-structured questionnaire in an online survey format (questionnaire shared via 'google forms'). The purpose of the questionnaire was to raise a wide range

of perspectives on the central problems and possible solutions for the interaction between the human and the natural context in the Amazon region. All SPSAS participants fulfilled the inclusion criteria to answer the questionnaire, i.e., being of legal age and voluntarily agreeing to the anonymous data usage.

During the first week of the SPSAS, all participants gather together in oral presentations by invited researchers, followed by deep discussions on the importance of a transdisciplinary approach in science. Once aware of the concepts discussed, as well as their variations and specificities, the participants were then invited to respond to our questionnaire, entitled: '*Bottlenecks and solutions for the inclusion of transdisciplinary science in socio-political decision-making*'. In the first part of this, we identified the profile of the participants, including gender, age, nationality, area of activity, region of activity, institution and sector of activity. Then the following questions were presented:

- (Q1) In your opinion, what are the main bottlenecks for promoting transdisciplinary science?
- (Q2) How to build a truly transdisciplinary science?
- (Q3) How to incorporate the cultural and social diversity of the Amazon into academic spaces?
- (Q4) How can science connect with the cultural and social diversity of the Amazon in spaces of political decision-making?
- (Q5) Have you ever participated in transdisciplinary science experiences?

Questions 1, 3 and 4 were elective, with closed answers, while questions 2 and 5 were discursive. The complete questionnaire can be consulted in the Supplementary Material (Annex I).

Ethics in accessing sensitive data

The participants gave their consent for the use of the informed data, in which the confidentiality and anonymity of their identity, as well as their personal data and their answers, were guaranteed. For this purpose, we included an item about permission and use of data for analysis in the body of the questionnaire.

Methodological script and data analysis

There were four main phases in our methodological framework (Figure 1). First, participants attended conferences related to the "Sustainable and Inclusive Amazon" to acquire knowledge and engage in inclusive dialogues - (I) inspi-

ration. Second, a space for exchanges and discussions was used to design the research strategy for this study - (II) construction of the questionnaire. Then, the sampling method was defined through a semi-structured digital questionnaire, which catalyzed data collection for analysis and subsequent discussion (phases III and IV, sampling and data analysis respectively). Questions with closed answers (Q1, Q3, Q4) were analyzed quantitatively in R language (R Core Team 2015). The open questions (Q2, Q5), as well as the discursive answers of Q1-Q5 were qualitatively analyzed and grouped by categories.

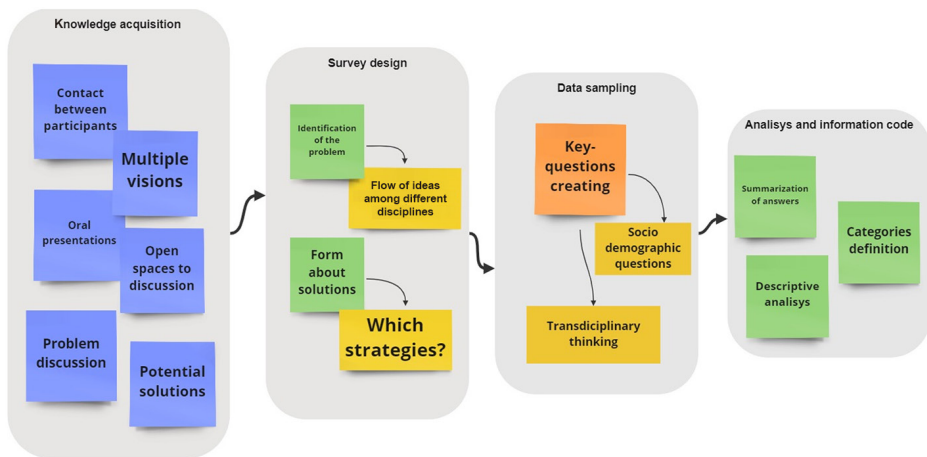


Figure 1 Methodological flow describing the steps for inspiration and reflection on transdisciplinary science, questionnaire construction, sampling strategy, and data analysis.

Study limitations

An obvious limitation in the present study is that we approached the transdisciplinary theme in a context where only researchers were present. We are aware about the need to diversify the participation of distinct actors, including and not exclusively indigenous peoples, environmental leaders, educators, politicians and artists in the creation of a transdisciplinary knowledge generation system in the Amazon. This reflection is an important part of this article and, even though it was not contemplated in the execution of this work, it was not neglected so that it can illuminate future actions. We tried our best to incorporate professional experiences and reports from academic spaces on the direct relationship with traditional peoples and communities. Whenever possible, we carefully insert this perspective into our discussions, taking into account the importance of treating this topic with due sensitivity.

Results

Next, we show the results obtained from the online questionnaire on transdisciplinarity for a sustainable and inclusive Amazon. The subsections correspond to the questions presented to the interviewers through the online form.

Participant's profile

In total, 66 questionnaires were answered, representing 70.97% of the participants in the SPSAS 2022. Of these, 35 declared themselves to be women, 29 men and two women CIS, aged between 29 to 64 years (average = 39), 28 to 67 (38) and 31 to 33 years (32), respectively (Figure 2A). The interviewed participants are from different nationalities, with a significant participation of Brazilians (79.5%), followed by Bolivians and Colombians (6.8% each) (Figure 2B). None of the interviewees identified themselves as members of a traditional or indigenous community.

Regarding the professional profile, most of the interviewees work as researchers in academic institutions (53%), 29% are doctoral students and the other activities are related to non-governmental organizations (NGOs, 9%) and government agencies (6%), and none of the participants declared working in the private sector (Figure 2C). Among the areas of knowledge of the participants, the major areas of Biological Sciences (39%) and Humanities (35%) stand out, with a wide range of specializations, predominantly Ecologists and Anthropologists (Figure 3).

The geographic distribution of the participants, both in terms of their origin and areas of activity in the Amazon, were primarily concentrated in Brazil and in the eastern Amazon region and Ecuador, respectively (Figure 4). However, 70% of the institutions where the researchers work are not installed within the limits of the PanAmazon.

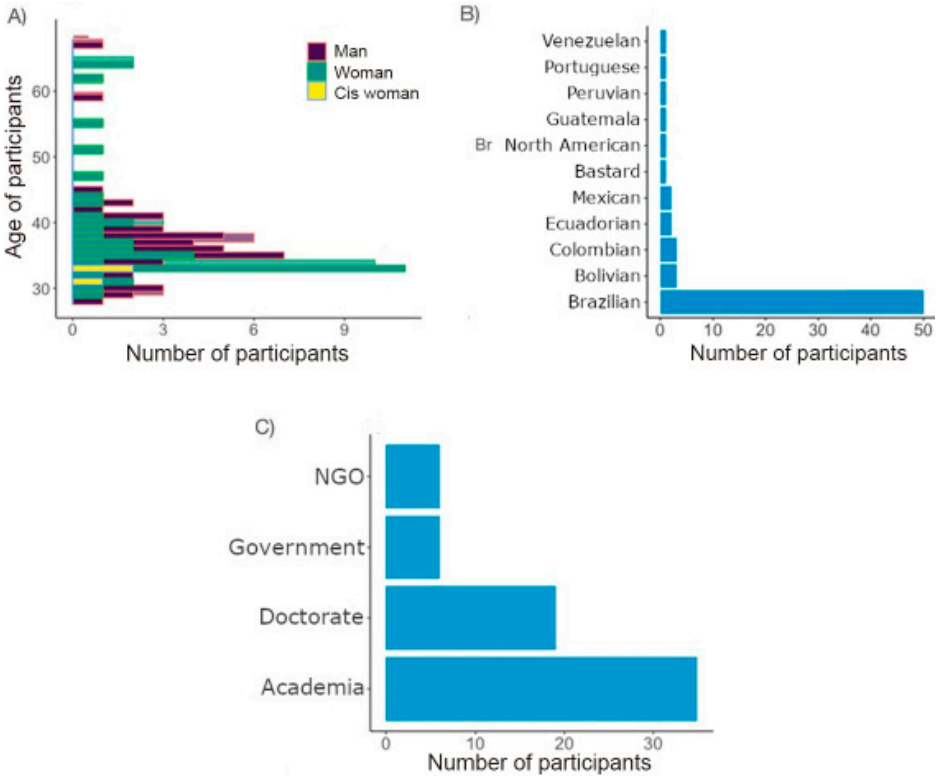


Figure 2 Profile of participants who responded to the semi-structured questionnaire on transdisciplinarity in Amazon conservation during the School of Advanced Studies on Inclusive and Sustainable Amazon 2022. A) Distribution of participants' age by gender; B) Nationality; and C) Sector of activity of the participants.

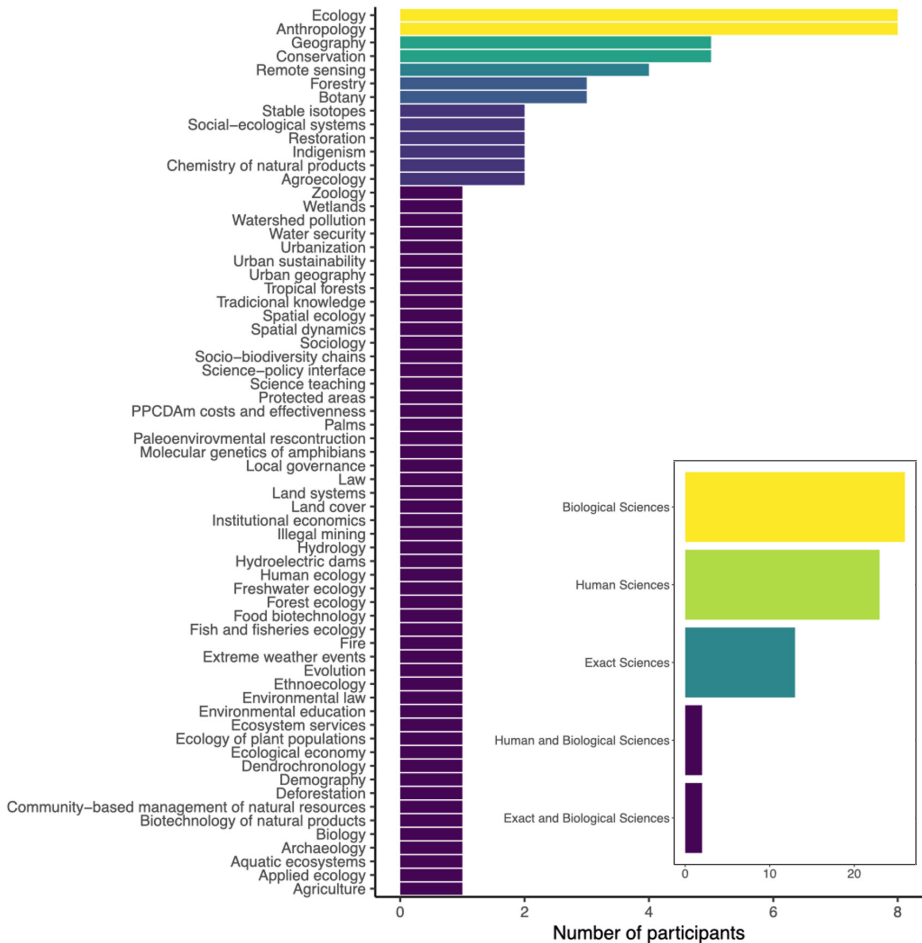


Figure 3 Categorization of participants who responded to the semi-structured questionnaire regarding the role of transdisciplinarity in Amazon conservation during the School of Advanced Studies on Inclusive and Sustainable Amazon 2022, by areas of expertise. The internal graph displays the areas of expertise grouped according to the major fields of activity of the interviewed participants.

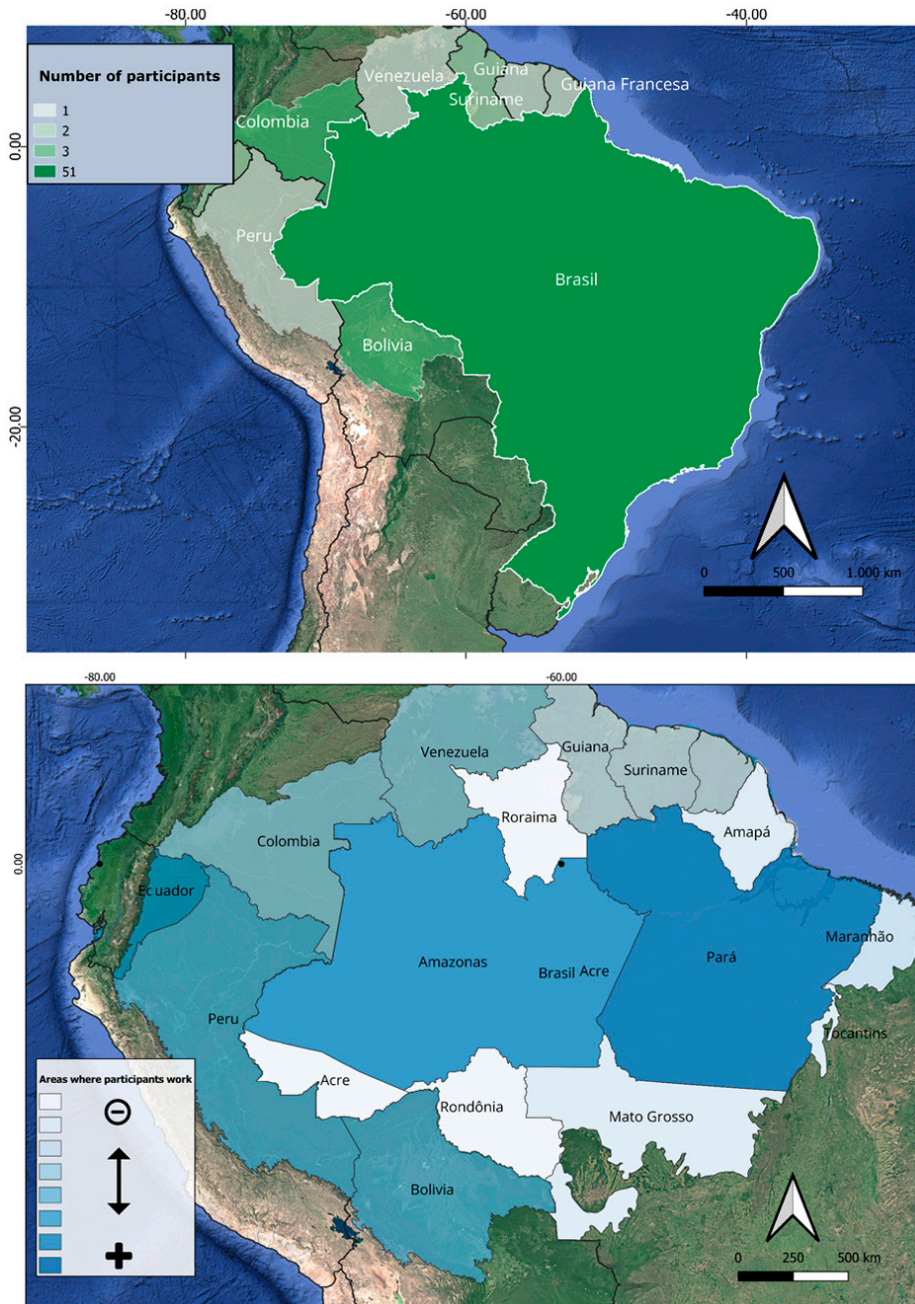


Figure 4 Map of the distribution in the Pan-Amazon region showing the nationality (above panel) and field of activity (below panel) of the participants of the School of Advanced Studies on Inclusive and Sustainable Amazon 2022.

Bottlenecks and solutions for the inclusion of transdisciplinary science in sociopolitical decision-making

Q1. Main bottlenecks promoting transdisciplinary science

The ranking of importance for the use of transdisciplinary science pointed training of scientists as the main bottleneck, followed by the devaluation of traditional knowledge and lack of spaces to promote knowledge integration. The non-inclusive language was mentioned but was less relevant (Figure 5). The participants also described other important points to achieve transdisciplinary in Amazonian science, including transdisciplinary methodologies combining practice and theory, recognition of transdisciplinary education in concourses, restructuring of methods, academic programs and tools to include transdisciplinary science, government interest, lack of resources and scientists’ interest in including other areas of knowledge, and others (Supplementary Material – MSQ1).

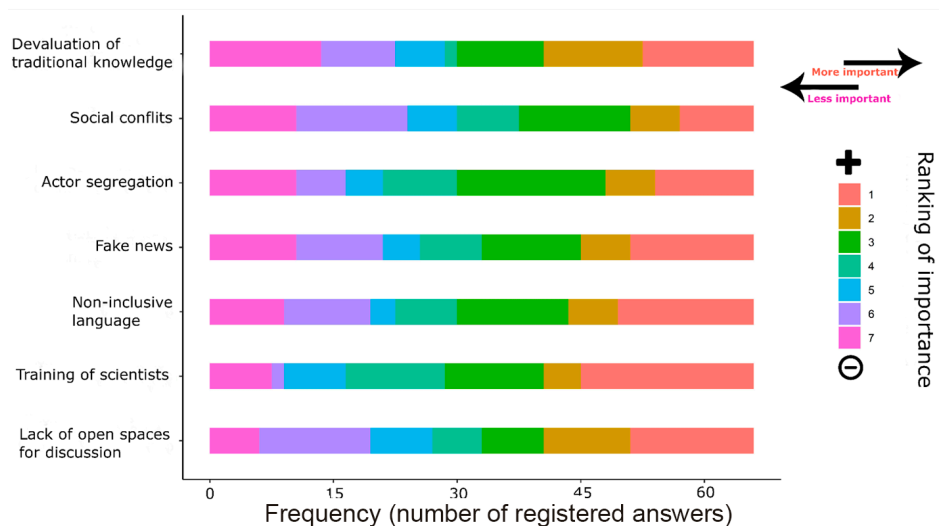


Figure 5 Main bottlenecks to promote transdisciplinary science identified by participants of the School of Advanced Studies on Inclusive and Sustainable Amazon 2022. The segments of the bars represent the frequency of participants who considered the bottlenecks more or less important in promoting transdisciplinary science.

Q2. How to build a truly transdisciplinary science?

Many responses mentioned time as an important point to develop transdisciplinary research, which needs to be “sufficient”, “longer”, “takes time” and “project deadlines are sometimes too short for transdisciplinary networking and

exchange to occur". The participants also brought up the need for "open", "horizontal co-construction" spaces, with "a variety of actors" that promote "dialogue" and "discussion", both between different actors and between different areas of knowledge. In addition, the need for changes in the formal structure of education, greater approximation between academia and other sectors, greater participation of marginalized people in scientific research processes and the origin of the Amazonian reality, and appreciation of non-scientific knowledge were pointed out. The ability to listen was also mentioned as a necessary practice for building transdisciplinary knowledge: "training to listen"; "Implementing a listening and caring policy that promotes co-constructed knowledge through experience."

The importance of "homogeneous" and "common" language and communication was mentioned so that "different actors can express themselves and be understood by others, as well as an education on how to behave and listen in different environments." In this sense, the suggestion of developing "literacy workshops in foreign languages" arose. Some skills were highlighted as necessary, such as "Respect for different opinions, acceptance of what is new and humility"; "Talking with multiple social agents"; "Fighting the egocentrism, Cartesianism, sexism and colonialism of scientists"; "Good communication" as well as collaboration and integration practices: "Integrating all actors and knowing the problems of each place"; "better integration"; "Integrate different actors and equally"; "Open interaction between different fields of knowledge, as well as with traditional knowledge."; "Through networking with scientists from other countries." In addition, the need to bring together different kinds of knowledge and establish how they are related and how they diverge"; "Creating a vast number of chains of transdisciplinary scientific networks". Only three answers said 'I don't know', one answer said it was a "Good question" and one researcher seems to have understood that the answer should come from the person who asked the question.

The complete answers can be found in the Supplementary Material (MSQ2). In summary, we highlight the following points: "developing research processes collaboratively from the beginning with different specialists (here understood as those who hold relevant knowledge, regardless of whether they are academics or not); design research projects that address concerns raised by civil society or that combine these concerns with gaps in scientific knowledge; combine methods developed jointly with stakeholders and experts that are verifiable and robust; establish dialogue between different ways of interpreting the world, treating them as complementary and not exclusive, but at the same time recognizing

different interpretations (sometimes antagonistic) for the same phenomena under study; truly transdisciplinary science must also be pursued without romanticizing the production of knowledge, but recognizing the different sources of uncertainty that can affect different systems of knowledge”.

Q3. Main pathways to incorporate the cultural and social diversity of the Amazon into academic spaces

The most mentioned mechanism for incorporating the cultural and social diversity of the Amazon into academic spaces was the need to apply traditional knowledge in research, followed by the creation of transdisciplinary spaces in discussions and the transdisciplinary training of scientists (Figure 6).

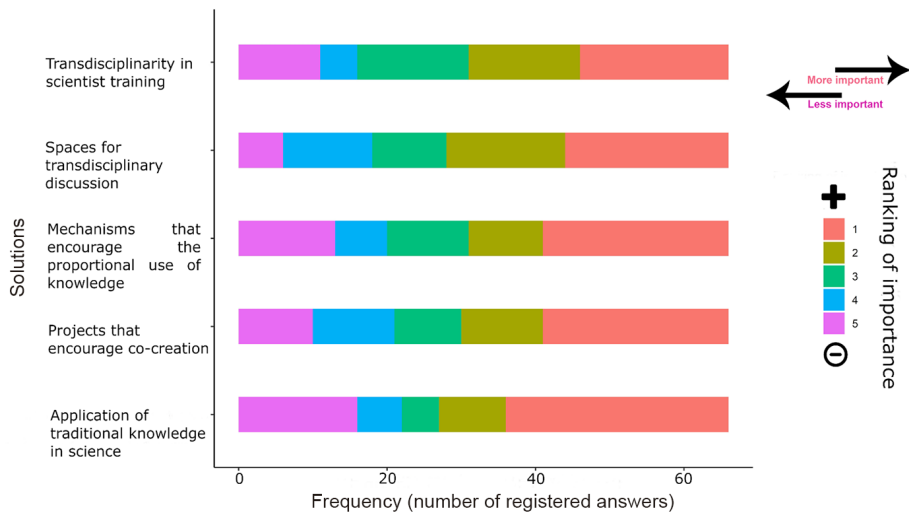


Figure 6 Main mechanisms identified by participants of the School of Advanced Studies on Inclusive and Sustainable Amazon 2022 for incorporating transdisciplinary and inclusive scientific practices within academic spaces. The segments of the bars represent the frequency of participants who considered the solutions more or less important.

Participants also mentioned other relevant points, such as local knowledge, indigenous language in knowledge production, themes proposed by the community, restructuring curriculum grids and ensuring the participation of representatives of other epistemologies in conventional science discussion spaces (MSQ3).

Q4. Main pathways to incorporate the cultural and social diversity of the Amazon in political decision-making

The co-creation of policies involving multiple actors was identified as the main mechanism for transdisciplinary inclusion in the Amazon, followed by the need for synthesizing scientific knowledge to enhance information accessibility (Figure 7). From the analyzed questionnaires, it was also possible to list other ways of incorporating cultural and social diversity in public policies, including the co-production of knowledge between decision makers and local actors and a greater connection between scientific and local concepts; definition of research themes based on listening to the actors' demands; recognition of science, create a network of environmental paradiplomacy; non-hierarchical stance towards other explanations of the same phenomena and creation of a transdisciplinary curriculum (MSQ4).

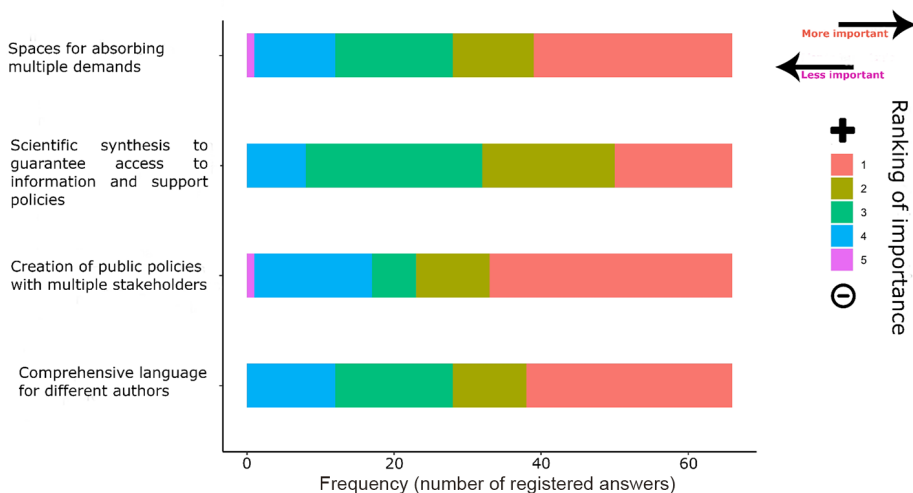


Figure 7 Main mechanisms identified by participants of the School of Advanced Studies on Inclusive and Sustainable Amazon 2022 for the inclusion of science as a support for decision-making in public policy spaces. The segments of the bars represent the frequency of participants who considered the solutions more or less important.

Q5. Participation in transdisciplinary science experiments and mechanisms that made the experience successful or unsuccessful.

In total, 63.6% of the participants had already had some kind of transdisciplinary experience, while 36.4% had never had any contact. Most of the answers (92%) were positive regarding the transdisciplinary experiences, and the main mechanisms highlighted for the success of the experiences were: listening, space and time for broader discussions, dialogue, comprehensive language and

communication, planning and common objectives, inclusion of different actors and areas of knowledge, participatory methods, experience and posture (see details of each mechanism in the supplementary material, MSQ5).

However, negative points were also listed in transdisciplinary experiences, such as: *not having a return to the community*; research projects *implemented only by purely academic interests did not prosper*; proposal of the research project to be conceived in a transdisciplinary way, but the execution to be carried out by groups separately; *not previously defining what it means to be interdisciplinary*, difficulties with language and/or oral expression (foreign/common language); and finally, *the greatest difficulty is the dialogue with the decision-making agencies*.

Discussion

The São Paulo School of Sustainable and Inclusive Amazon Science (SP-SAS Amazônia) featured researchers from different countries and regions of the Amazon. In summary, the critical issues related to the sustainable development of the Amazon include: (I) sensitizing scientists about interdisciplinarity, transdisciplinarity, and traditional knowledge; (II) considering different perspectives, including local communities and other decision-makers to favor inter and transdisciplinarity; (III) co-create public policies with multiple actors to connect science and politics. In this work, we demonstrate the importance highlighted by SPSAS Amazônia participants in creating spaces for dialogue with the participation of different actors to represent the social, cultural, and epistemological diversity in the Amazon. We also discuss alternatives to overcome challenges in the development and application of transdisciplinarity in broader contexts to promote the conservation of Amazonian biodiversity.

Transdisciplinarity has become an essential tool in approaching complex subjects such as socio-ecological sustainability, mainly due to its ability to promote co-design, co-production, and co-dissemination of knowledge (Mauser *et al.* 2013; Page *et al.* 2016). From this perspective, the importance of considering local ecological knowledge (LEK) is increasingly perceived to better understand the dynamics of Amazonian environmental systems. According to the responses of the Advanced School participants, a transdisciplinary approach, involving several disciplines, is essential for this purpose. However, scientists must be open to adopting transdisciplinary approaches that value both practical science and theory, incorporating traditional knowledge. The LEK developed over millennia of coexistence between communities and their natural environments (Berkes 2004).

Transdisciplinary development research (TDR) for example, has the possibility to go beyond the limits of traditional research, engaging and articulating with the underlying causes of the sustainability issue, due to its emphasis on the co-production of solution-oriented knowledge, seen as a catalyst process for systems transformation (Marshall *et al.* 2018). The emphasis of approaches to TDR is to inform action and policy making. A fundamental feature is the possibility of building alliances and opening cognitive, normative, social and material spaces/arenas that are dynamic, responsive and lasting for the coordinated exercise of agency in this new way of thinking and acting in politics.

In this sense, it is important to encourage policies that recognize and promote transdisciplinary approaches in the contemporary context, overcoming linguistic and institutional barriers that hinder the promotion and sustainability of these initiatives. Indigenous peoples and traditional communities in the Amazon have a profound knowledge of the natural environment, transmitted from generation to generation and based on their cultural and subsistence practices (Berkes 2004). This knowledge is fundamental for understanding ecological processes, socio-environmental dynamics and developing strategies for conservation and sustainable use in the Amazon region. Valuing and respecting LEK is essential for fairer and more effective management of Amazonian ecosystems (Estevo *et al.* 2022). Therefore, the development of public policies for conservation and environmental management in the Amazon requires the integration of different areas of knowledge, not only for an in-depth understanding of socio-ecological phenomena, but also to increase the legitimacy of findings and recommendations (Fearnside 2010).

On the other hand, interdisciplinarity, even with a focus on support for solutions, does not necessarily guarantee an inclusive science (Persson *et al.* 2018) and in this sense, transdisciplinary principles and assumptions need to be adopted for urgent social transformation to actually occur (Popa *et al.* 2015), as also mentioned in the responses obtained. Among the main paradigms of transdisciplinarity (Nicolescu 2014) is the creation of a field that aims to build knowledge with a focus on sustainability, in which there is the possibility of stimulating the meeting of different knowledge, visions and practices, promoting symmetrical institutional approaches and, according to our results, horizontally co-constructed. Or, furthermore, the *"creative use of models, analogies and insights from a variety of fields and disciplines [...] Its objective is the comprehension of the present world, for which one of the imperatives is the unity of knowledge"* (Nicolescu 2014). Within this understanding, aspects reported by the participants are involved, notably "listening training" associated with a series of skills

such as “respect for divergent opinions”, “welcoming the new” and “humility”, at the same time that this same understanding needs to consider the different terminologies and language specific to each discipline. Expanding researchers’ listening involves the development and absorption of the concept of alterity in research. Otherness is fundamental to improving science, as it recognizes the importance of different perspectives and experiences in fully understanding a phenomenon. Valuing otherness in science contributes to more accurate, reliable and representative results of the diverse communities served by science (Harding 1998), aligned with the social, economic and institutional aspirations of marginalized groups (Boisselle 2016).

Our results also indicate the time scale for the actions in these spaces to take place, being necessary to consider the natural time for the development of transdisciplinary research, which needs to be “sufficient”. This does not correspond to the understanding that knowledge systems must be transdisciplinary or that we need a single transdisciplinary science. Science exists by itself, however, its results when applied must be inserted in a transdisciplinary approach to be added to other perspectives and epistemologies, embarking on different ways of seeing, analyzing and feeling the world. A “truly transdisciplinary science” could make knowledge production systems have to give up some important aspects inherent to each one. We use here, especially, the definition: “transdisciplinarity as a discipline and as a way of being” (Rigolot 2020). Or as one of the participants responded: “Transdisciplinarity should not be seen as an end, but a means of seeking answers or solutions to complex problems or issues that cross-disciplinary fields”.

As part of possible solutions to catalyze the inclusion of the Amazon’s social and cultural diversities in knowledge development environments, emphasis was placed on the application of traditional knowledge in the design and conduct of research, recognizing traditional knowledge systems. This same solution was pointed out by many as having less value, which confirms the challenges of implementing a science that encompasses multiple views and disciplines. This approach is increasingly recognized by researchers, activists and local communities not only in the Amazon, but throughout Latin America. Western science has historically been imposed on local cultures and societies, ignoring their histories, knowledge and ways of life, resulting in the devaluation and marginalization of local knowledge, as well as the exploitation of natural and human resources in the region for the benefit of external interests (De Lima Grecco and Schuster 2020). The decolonization of science - as we can call the aforementioned points - requires transformation in the practices and values that guide the production

of scientific knowledge from the recognition of the cultural and epistemic diversity of the region, establishment of partnerships based on reciprocity and solidarity, and work in favor of a fairer, more inclusive and socially responsible science education (Blackie and Adendorff 2022).

The recognition, appreciation, and inclusion of traditional Amazonian knowledge cannot depend exclusively on the presence of hegemonic science actors in the spaces of discussion, training, and research. It must be led by canonical institutions, funding and defining scientific knowledge, as well as political decisions. It is essential to understand traditional knowledge as equally valid, having its own empiricism, method, reflection, and analysis, even in a different way, but on an equivalent level. This approach, perhaps, allows us to bring together academic work and social participation, as pointed out by Merçon (2018), being always attentive to the instrumental use of social research. Ailton Krenak (2022) speaks of affective alliances, especially when referring to the experience of the *Aliança dos Povos da Floresta*, as a concept that does not necessarily seek equality of knowledge, but perhaps equivalences. And here another link can be made with the discussion proposed by Almeida (2013) on ontological connections and disconnections in specific contexts of research and knowledge in the discussion of pragmatic encounters.

The implementation of a transdisciplinary science also goes through a heated debate about the need for a new science that requires a more comprehensive approach, going beyond technical skills or traditional “hard skills”, and includes socio-emotional skills or “soft skills” (Holloway and Hill 2021). Hard skills generally refer to discipline-specific technical skills, such as the ability to perform statistical analysis or design experiments. However, to build a fairer, more inclusive and socially responsible science, it is also important to develop skills such as empathy, collaboration, clear communication and conflict resolution - the so-called soft skills (Schulz 2008). These skills are critical to working with diverse communities and groups, building alliances and partnerships based on reciprocity and solidarity, and addressing the complex social, environmental, and ethical challenges we face today (Holloway and Hill 2021). Associated with multiple skills, it is necessary to ensure that scientific knowledge is applicable to different realities, transforming complex results into useful information for people’s daily lives. This is in line with our results, which emphasize the co-creation of policies involving different actors, together with the reanalysis and recontextualization of scientific knowledge, to improve the use of science in science-driven policy.

Although quite challenging, most of the participants went through transdisciplinary experiences during their training, evidencing several specific initiatives for the promotion and implementation of transdisciplinarity. Among the points highlighted as necessary for the success of the activities, we highlight, in addition to the creation of transdisciplinary spaces, the use of accessible languages for greater integration between different groups of actors and the co-creation of strategies and public policies for the development of sustainable and socially fair solutions for the Amazon. In this context, a greater articulation between large research groups and funding agencies is discussed so that these experiences can be connected to a long-term transformative process that is fundamental to consolidate transdisciplinary practices in research groups. It is noticed in the answers that it is easier to point out problems (Q1) than solutions (Q3 and Q4). However, more positive than negative points are pointed out when referring to the transdisciplinary experiences lived by the participants (Q5).

Conclusion

The implementation of transdisciplinary and inclusive science for the resolution of socioecological problems in the Amazon requires consideration of the value and forms of inclusion of traditional knowledge, adequate spaces and times for broader discussions and adjusted language of communication between the parties. The planning and execution of research associated with a broad and philosophical view of the research object, bringing them closer to biophysical and social realities through co-creation, is crucial for producing results that adhere to public policies and decision-making.

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Conflict of Interest – The authors declare that they have no conflicts of interest related to the publication of this manuscript.

Ethics – This study does not involve human subjects and/or clinical trials that should be approved by the Institutional Ethics Committee.

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Annex I

SUPPLEMENTARY MATERIAL

RESPONSES

This section presents the participants' responses in detail, synthesizing broader ideas without losing the individual responses' originality.

MSQ1. Key bottlenecks to promote transdisciplinary science:

- i - Application of transdisciplinary methods in practice, not just in theory;
- ii - Lack of recognition of transdisciplinary backgrounds in competitions;
- iii - Lack of academic structures, programs, and curricula, as well as tools and methods, to develop transdisciplinary science;
- iv - Government interest;
- v - Precision with data and research;
- vi - Leadership;
- vii - Lack of alignment of roles and responsibilities between academic and non-academic partners;
- viii - Lack of encouragement from funding agencies, and evaluation criteria for researchers and undergraduate and postgraduate courses that do not value transdisciplinarity;
- ix - Lack of empirical studies, as most projects do not start due to social demand but academic interest;
- x - Lack of interest among scientists in including other knowledge systems;
- xi - Transdisciplinary training;
- xii - Lack of a network of connections between different expertise and institutions;
- xiii - Colonial perspectives;
- xiv - History;
- xv - Maintenance of traditional bases and systems among university professors;
- xvi - Academic colonialism in developing countries at various scales and levels, including regionalism within Latin America and countries;
- xvii - Lack of funding for transdisciplinary research and seed grants to co-create relevant questions and proposals.

MSQ2. How to build truly transdisciplinary science?

Details of the suggestions mentioned by the participants of SPSAS 2022 in the open field:

Spaces/Scenarios:

Promoting a safe environment for each person to share their knowledge.

Valuing this knowledge and creating professional spaces for the researcher to work in.

It is important to find scenarios that require transdisciplinary research. Integral problems stem from integral approaches, where disciplines coincide in time and space to solve them.

Work outside the office, dialogue with society, and participate in political spaces.

Changes in the formal education structure:

Modifying the entire education system; Integrating the transdisciplinary approach into various school curricula, from high school to postgraduate education; More participatory and simplified education; Inclusive transdisciplinary education at all levels and scientific disciplines.

Closer alignment between academia and other sectors:

Transdisciplinary science should begin within the academic space, at the beginning of any undergraduate program, to establish a solid foundation and a unique path. Extension projects must be more valued within the university to instill the same pleasure of execution in a scientist as in a research project. The connection between the community and academia must be strong for transdisciplinary science.

Bringing academia closer to other sectors, peoples, and communities is an extremely important step.

(...) pursuing solutions involving academia should go hand in hand with the affected sectors.

Scientists should receive training to deeply understand how different knowledge and sciences are constructed and how they are useful for solving concrete problems. Properly training scientists and promoting the integration of multiple actors in policy development.

An example of this is the "Notório Saber" titles for traditional masters and mistresses granted by some universities in Brazil, which allow these knowledgeable individuals to navigate the university in recognized positions and sometimes with resources for research and teaching activities.

Starting at the undergraduate level, introducing students to courses and lectures to learn about this, but more importantly, they learn to work with other people. Always include community leaders and teachers in projects.

Funding agencies and academia should require that research is more accessible (from the initial collaboration phase to the final stage with results) to local communities, including urban and rural areas, with appropriate communication and language.

Greater participation of marginalized people in scientific research processes and in the origin of the Amazonian reality:

Inclusion of underrepresented parties; Involvement of local actors as researchers. Ensuring the inclusion and presence of historically excluded peoples in decision-making and knowledge formation.

We need more people from the Amazon showing the Amazonian reality.

Ensuring the participation of representatives from other knowledge systems in spaces related to the Amazon.

Valuing traditional knowledge and including traditional populations in scientific debates.

Social inclusion, considering all social classes and not just distinct groups. The tendency is always to think in terms of groups rather than how society, especially in Brazil, is "organized."

Transdisciplinarity is a political issue, and politics cannot be carried out without a body. The body I seek for it is a hybrid, human and non-human body.

Valuing non-scientific knowledge:

Recognizing other worldviews as sources of wisdom.

Not excluding traditional knowledge; Using strategies adapted to the reality of each population; Involving and valuing different forms of knowledge.

Considering it as the field of the new, of contingencies. Transdisciplinarity must stir epistemological and ontological questions, as it is not only associated with the path in constructing knowledge but also with the agencies of those who construct it. For this, it is crucial to recognize the multiple alterities in world constructions.

Making the process of consultation, dialogue, and dissemination with the local communities involved an ethical principle of research, valuing traditional knowledge and collective memory and assuming social contribution through the production of concrete and applicable results as a commitment.

Ensure that IPLCs (Indigenous Peoples and Local Communities) have their basic services and rights respected, so they can more easily engage in science. In fact, place IPLCs in stable positions of academic power so they can create research and study programs.

Methods and approaches:

Conduct applied science based on socio and ecosystemic needs.

Build and approve transdisciplinary projects.

Interdisciplinarity arises from the practice of research. It requires a group of professionals with different backgrounds willing to step out of their comfort zones.

Align research objectives with the solution of problems according to the perception of different stakeholders.

Include art, be creative, think of (action) solutions beyond disciplinary understandings of specific questions and doubts to be addressed.

Shift the orientation of science from mere data to transformational science. Implement methodologies that include aesthetic aspects and diverse languages.

Indigenous and traditional peoples should be involved in the design of research and public policies. The themes of these instruments should be determined by these people.

Start by having a shared vision of what is desired and the objectives; hold workshops to identify values shared by project members; hold workshops to identify biases and underlying epistemologies that each person uses; build a shared vocabulary; start with the problem.

1. Identify a working group that can incorporate an integrative perspective for the research question; 2. Co-create from the idea to the development of proposed products; 3. Listen and dialogue among different team members of the project. 4. Identify the capabilities and limitations of each team member; 5. Maintain frequent meetings/sessions; 6. Assessments and feedback on activities among team members.

Academic colonialism, racism, and socioeconomic inequality homogenize scientific thought and hinder transdisciplinary research. Without addressing these issues, we can only imagine what would be transdisciplinary from a Eurocentric and non-inclusive perspective.

I think it's a challenge because it requires some systemic changes, including the evaluation of scientists' output and, of course, transdisciplinary training as well.

MSQ3. Key ways to incorporate the cultural and social diversity of the Amazon into academic spaces

In addition to the points mentioned, the following aspects were raised:

i - Local knowledge of cultural systems;

ii - Developing policies to value and incorporate indigenous languages and local dialects in the knowledge production processes;

iii - Challenging and critiquing our own ways of viewing the world and knowledge systems;

iv - Supporting inter/multicultural education and promoting the dialogue of knowledge;

v - Research topics indicated and discussed with traditional peoples, acting as researchers and data analysts, participating in all stages of knowledge production;

- vi - Placing International Private Leased Circuits (IPLCs) in positions of power, such as FAPESP and the Brazilian Academy of Sciences;
- vii - Valuing scientific, traditional, and indigenous knowledge equally;
- viii - Ensuring that all actors have access to information;
- ix - Leveraging and valuing university extension course structures with a transdisciplinary focus, encouraging larger funding and longer projects that respect a consolidated schedule and process for solving complex socio-environmental problems;
- x - Ensuring the participation of representatives from other epistemologies in conventional science discussion spaces;
- xi - Establishing trust-based interpersonal relationships;
- xii - Preventing colonialism, structural racism, and socioeconomic inequalities in research agendas and institutions, expanding access to financial resources for minorities.

MSQ4. What are the key ways to incorporate the cultural and social diversity of the Amazon into political decision-making?

- i - Facilitate the co-production of knowledge between decision-makers and local actors, creating bridges between local and scientific concepts, perspectives, and knowledge to inform policies that can integrate common objectives and issues;
- ii - Define research topics based on listening to the demands of the actors and jointly reflect on the causes of the presented problems;
- iii - Recognition by decision-makers of science as a planning tool;
- iv - Create a network of environmental paradiplomacy (various actors with different experiences) to address environmental issues;
- v - The process of consultation, dialogue, and dissemination with community organizations/associations as an ethical principle of research;
- vi - Identify the governance systems of common goods at the local level and public policies that are built from the bottom up;
- vii - Think of co-creation as a way to ensure implementation;
- viii - A non-hierarchical approach to other explanations of the same phenomena; the ability to collaborate for new ways of thinking and solving "urgent issues";
- ix - Create a transdisciplinary curriculum to connect and value the knowledge and needs of traditional and ancestral peoples;
- x - Listen to demands and understand the realities in the field.

MSQ5. Participation in transdisciplinary science experiences and mechanisms that made the experience successful or unsuccessful.

Details of the mechanisms mentioned as positive in previous experiences by participants in SPSAS 2022:

Listening: "broad listening," "listening to each member's demands," "listening to the opinions of people from different areas on the same topic," "listening to traditional peoples for innovative practice with adherence," "respectful listening and idea exchange."

Space/Time: "time for dialogue," "spaces to hear demands," "discussion and exchange of approaches in a horizontal, flexible, and proactive environment were the most important inputs."

Dialogue: "dialogue about activities," "dialogue and the need to exchange ideas on a common theme."

Language/Communication: "Adoption of local languages in meetings, project concept glossaries"; "learning another language in science/creating shared vocabulary"; "detecting aesthetic languages, social codes, and dynamics upon which to project methodological proposals departing from the scientific conventionality of data science"; "facilitating appropriation by local actors."

Planning/Common Objectives: "having a clear goal for the work"; "clearly defined roles and responsibilities"; "co-creation with representatives of other knowledge production systems at all stages of the approach."

Inclusion of Different Actors and Areas of Knowledge: "It is very important to be attentive to the approaches of each discipline and include them as fundamental in defining strategies, action plans, or, in short, solutions"; "inclusion in discussion groups of many members from different cultures and different traditional peoples from various parts of the planet"; "better relationships between areas"; valuing "all knowledge, and everyone felt equally a part of the group"; participation of "anthropologists, philosophers, artists, transgender individuals, children"; "recognition of the capabilities and aspirations of traditional communities"; participation based on "gender equality, race, location of activity, subject of activity, level of education, etc. (diversity of actors)."

Method: application of participatory methods; local validation of field methodology; fieldwork in the community, respecting the schedules and rules of interlocutors; consideration of various forms of knowledge, information, data, and evidence.

Experience: researchers with previous experience working with traditional peoples and local communities; participants who are genuinely prepared to negotiate and not to impose views; "international and national experience in other universities, researching different ecologies, environments, and cultures."

Attitudes: joint action, goodwill, patience, “being humble is a good starting point,” respecting new perspectives, stepping out of one’s comfort zone, respect for different perceptions, a sense of reality (moving forward with what is possible), tolerance, respect, constant communication, contributing to autonomy. Mutual trust is based on the sincerity of purposes and expectations, shared (and rotating) leadership, clear communication strategy, trust, and interpersonal skills development among participants, as well as openness and inclusion of diverse perspectives.

Others: good governance of communities; epistemological and ontological symmetry between sciences, environmental knowledge (Enrique Leff); Freirism. In addition, although participants were not asked to describe their experiences in transdisciplinary research, many chose to do so. One response stated that their experience was “very relevant and powerful.” Participants shared the following transdisciplinary science experiences:

- ◆ Community Archaeology Project for Ethnoeducational Heritage “For a Living Fort Museum: Public Archaeology with the Quilombolas of Fort Príncipe da Beira in Times of Pandemic,” an experience that won the 10th edition of the largest award in the field granted by IPHAN - the Luiz de Castro Faria Award - in the scientific article category.
- ◆ Agroecological Project: carried out by a diverse team (academics, farmers with training in agroecology, local residents, and indigenous people), where dialogue occurred in a horizontal manner, and most of the work was done in the field rather than in classrooms.
- ◆ Participatory and Sustainable Management of Pirarucu, specifically a course for learning how to count pirarucu, where novice fishermen learned to organize their perceptions of fish behavior for population surveys. Technicians and experienced fishermen shared their knowledge about pirarucus, sparking conversations with the students. The course included elements of ecology theories and traditional knowledge of fishermen about pirarucus. The joint coordination of the activity allowed multiple perspectives on fish and lakes, with both types of knowledge being considered valid without hierarchy. Experienced fishermen also guided students in practical fish counts in lakes, providing empirical guidance in the collective knowledge-building process.
- ◆ Alternation Pedagogy: a model recognized by the Ministry of Education in Brazil for education in rural areas, prioritizing modular curricula adapted to the rural reality and the traditional knowledge of these communities.
- ◆ Aesthetic Pedagogy: a proposal that seeks to identify convergent elements to work from an Autopoietic and Transdisciplinary perspective, incorporating art concepts into all subjects of the elementary school curriculum, enabling the emergence of a Pedagogy of the Sensitive.

- ◆ Cartographies/Social Mapping with Traditional Peoples and Communities: In this research experience, the positive aspects mentioned included the systematization, valorization, and dissemination of traditional knowledge in the Western pattern, materializing, recording, and translating oral and empirical knowledge into a universal cartographic language. However, the challenge and difficulty of this experience were the limited time to overlay and deepen the records of these traditional knowledge cartographies with scientific information already established (ecological analyses, data on socio-environmental conflicts, areas sensitive – hot spots, areas of greatest biodiversity, demographic and socio-economic data).
- ◆ The collaborative development of a book with anthropologists, biologists, and young local researchers from the Terra do Meio Extractive Reserve (RESEX) in Altamira, PA. The book focuses on the research results related to the management of Brazil nut groves, wildlife, agricultural fields, forest regrowth, and the daily life of the riverine communities, among other topics. The research was conducted between 2016 and 2020, and the writing process began in June 2021, but it has not been completed yet. This experience required a significant amount of time for dialogue, multiple revisions of the texts based on suggestions from all participants, and the need for each person to adapt their personal expectations regarding the outcome of the work. Effective non-violent communication and mediation were necessary at various stages.
- ◆ A vocational training course for Indigenous Agroforestry Agents in Acre, which aims to provide intercultural training at the high school level.

Questionnaire

Copy of the digital questionnaire sent to the participants of SPSAS 2022, titled **"Inquiry about transdisciplinary science."**

Transdisciplinary Science – Connecting Different Worldviews

This questionnaire aims to capture the perception of SPSAS 2022 participants regarding their current and future experiences in applying sustainable and inclusive transdisciplinary science in the Amazon. The responses will be analyzed and discussed to create a guidance manuscript for transdisciplinary practices.

Here, we use the term **"transdisciplinary science"** as a discipline that includes non-academic stakeholders in the knowledge production process and as a way of being in terms of researchers' personal dispositions and expression in multiple spaces.

Questions

Participant's General Information

- ◆ Email
- ◆ Gender
- ◆ Age
- ◆ Nationality
- ◆ Do you identify as a member of an Indigenous/traditional community?
If yes, please specify.
- ◆ In which region of the Amazon do you work?
- ◆ Area of expertise
- ◆ Institution
- ◆ Position/sector (Ph.D. student, Academic researcher, Private sector, NGO researcher, Government researcher).

Questões específicas/abertas

Specific/Open Questions

Q1. List, in order of importance, the main challenges in promoting transdisciplinary science (1 = most important). If there are other relevant points, please describe them.

(Non-inclusive language, Social conflicts, Fake news, Segregation of stakeholders, Lack of transdisciplinary training for scientists, Undervaluation of local knowledge, Lack of spaces that promote the integration of knowledge, among others.)

Q2. How to build truly transdisciplinary science?

Q3. How to incorporate the cultural and social diversity of the Amazon into academic spaces? List in order of importance (1 = most important). If there are other relevant points, please describe them.

(Valuing traditional knowledge in research development, Including/creating transdisciplinarity in the curriculum, More inclusive discussion spaces with actors from underrepresented groups, Co-created extension projects with communities, Creating mechanisms to reconcile different forms of knowledge, among others.)

Q4. How can science connect to the cultural and social diversity of the Amazon in political decision-making spaces? List in order of importance (1 = most important). If there are other relevant points, please describe them.

(Co-creation of public policies with actors from different spheres, Scientific synthesis to improve access and use of information, Accessible and understandable language for different actors, Implementation of spaces to listen to the demands of different actors.)

Q5. Have you ever participated in transdisciplinary scientific experiences (yes or no)?

Q5.1. If you answered yes to the previous question, please identify some mechanisms that made the experience successful or unsuccessful.

Authorization

If formal publication is required, do you authorize using the provided data as anonymous (yes or no)?

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