# Exploring Collaboration Between Engineers, Data Scientists, and Environmental Specialists in Sustainable Technology Development

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**Abstract**

This qualitative study aimed to explore how engineers, data scientists, and environmental specialists collaborate in the development of sustainable technologies in Brazilian organizational and project contexts. A qualitative descriptive design was used to examine professional experiences of interdisciplinary collaboration in sustainable technology development. Data were collected through semi-structured interviews with 27 participants from Brazil, including engineers, data scientists, and environmental specialists involved in renewable energy, circular economy, water management, environmental monitoring, smart-city, and climate-analytics projects. Participants were selected purposively to ensure disciplinary diversity and direct experience in collaborative sustainability-oriented technology projects. Interviews were conducted online and face-to-face, lasted between 45 and 75 minutes, and continued until theoretical saturation was reached at the twenty-fourth interview, followed by three confirmatory interviews. Audio recordings were transcribed verbatim and analyzed using thematic analysis supported by NVivo software. Five main categories were identified: shared sustainability problem framing, translation across disciplinary languages, data-mediated integration, negotiation of technical-environmental trade-offs, and organizational conditions for collaborative innovation. Participants described collaboration as most effective when teams moved beyond sequential expert contribution and developed shared problem definitions, common indicators, and iterative feedback loops. Data dashboards, environmental impact models, prototypes, and regulatory matrices functioned as boundary objects that helped professionals coordinate without eliminating disciplinary differences. However, collaboration was constrained by incompatible timelines, different evidentiary standards, fragmented data ownership, and tensions between engineering feasibility, algorithmic performance, environmental integrity, and commercial pressure. Sustainable technology development depends not only on advanced technical expertise but also on structured interdisciplinary collaboration. The findings suggest that engineers, data scientists, and environmental specialists need shared evaluative frameworks, translational routines, participatory data governance, and organizational support to integrate environmental knowledge into technology design. Strengthening these collaborative capabilities can improve the relevance, legitimacy, and sustainability performance of emerging technologies.

**Keywords:** sustainable technology; interdisciplinary collaboration; engineers; data scientists; environmental specialists; qualitative research; Brazil; thematic analysis

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## 1. Introduction

Sustainable technology development has become a central concern for organizations, governments, and research institutions seeking to respond to climate change, biodiversity loss, resource scarcity, and the broader challenges of sustainable development. Contemporary sustainability problems are not merely technical problems; they are complex socio-ecological problems in which engineering systems, digital infrastructures, environmental processes, economic incentives, regulatory frameworks, and community needs interact. Sustainability science emerged precisely to address such dynamic relationships between nature and society and to produce knowledge that can support action under uncertainty (Kates et al., 2001). Within this context, sustainable technology development requires more than the invention of cleaner devices, digital platforms, or resource-efficient processes. It requires collaborative knowledge production among professionals who understand materials, infrastructures, algorithms, ecological impacts, stakeholder expectations, and long-term environmental consequences.

Engineers, data scientists, and environmental specialists occupy increasingly interdependent roles in this process. Engineers contribute expertise in design, systems integration, prototyping, safety, reliability, production constraints, and infrastructure feasibility. Data scientists contribute capabilities in data modeling, predictive analytics, machine learning, sensor integration, optimization, and decision-support systems. Environmental specialists contribute knowledge of ecological systems, environmental impact assessment, climate risk, regulatory compliance, biodiversity, natural-resource management, and sustainability indicators. In principle, the integration of these forms of expertise can generate technologies that are technically feasible, data-informed, environmentally responsible, and socially relevant. In practice, however, interdisciplinary collaboration is often difficult because each professional group uses different concepts, methods, standards of evidence, time horizons, and definitions of project success.

The growing relevance of data science and artificial intelligence has intensified this need for collaboration. Digital technologies can support sustainability by improving environmental monitoring, optimizing energy and resource use, identifying climate risks, supporting circular-economy systems, and enabling more adaptive governance. Vinuesa et al. (2020) showed that artificial intelligence may support progress toward many Sustainable Development Goal targets, while also creating risks when governance, equity, transparency, and environmental costs are neglected. Similarly, Nishant et al. (2020) argued that artificial intelligence for sustainability should be understood not only as a technical instrument but as part of broader environmental governance and organizational transformation. George et al. (2021) described digital sustainability as a field in which digital innovations are used to address grand challenges such as climate change and sustainable development. These contributions suggest that data-driven sustainable technologies cannot be evaluated solely through technical accuracy, efficiency, or scalability. They must also be assessed according to environmental validity, social consequences, accountability, and institutional fit.

Interdisciplinary collaboration is therefore fundamental to sustainable technology development. Transdisciplinary and interdisciplinary approaches in sustainability research emphasize the integration of multiple bodies of knowledge to address real-world problems (Lang et al., 2012). Such collaboration is especially important when solutions must move across boundaries between scientific analysis, technological design, organizational implementation, policy requirements, and user practices. Cash et al. (2003) argued that knowledge systems for sustainable development become more effective when they produce knowledge that is salient, credible, and legitimate. This framework is useful for understanding collaboration among engineers, data scientists, and environmental specialists. Engineering knowledge may be credible in relation to technical performance, data-science knowledge may be credible in relation to analytic precision, and environmental knowledge may be credible in relation to ecological validity and regulatory relevance. However, sustainable technology projects require these forms of credibility to become mutually intelligible and practically actionable.

One major difficulty in such collaboration is the existence of knowledge boundaries. Professionals from different disciplines do not simply possess different information; they often organize reality through different assumptions and problem-solving routines. Engineers may ask whether a design can be built, maintained, and scaled. Data scientists may ask whether data are sufficient, models are robust, and predictions are accurate. Environmental specialists may ask whether the technology reduces harm, respects ecological limits, satisfies compliance requirements, and avoids unintended impacts. These questions are complementary, but they may also generate conflict. Star and Griesemer's (1989) concept of boundary objects is particularly relevant here. Boundary objects are artifacts, models, documents, or tools that are flexible enough to be interpreted by different groups but stable enough to support coordination. In sustainable technology development, examples may include dashboards, environmental impact matrices, life-cycle assessment models, prototypes, maps, datasets, and regulatory checklists. Carlile (2002) further explained that innovation across knowledge boundaries requires not only knowledge transfer but also translation and transformation. This means that interdisciplinary teams must do more than exchange information; they must reshape assumptions, priorities, and design choices through collaborative work.

Sustainability-oriented collaboration also requires specific competencies. Wiek et al. (2011) identified systems-thinking, anticipatory, normative, strategic, and interpersonal competencies as central to sustainability problem-solving. These competencies are highly relevant to teams developing sustainable technologies. Systems thinking enables professionals to understand how technical components, environmental processes, and social systems interact. Anticipatory competence helps teams consider long-term effects, future risks, and unintended consequences. Normative competence supports reflection on values, environmental goals, and ethical trade-offs. Strategic competence enables movement from analysis to implementation. Interpersonal competence supports communication, negotiation, and collaboration across disciplinary differences. In technology projects, these competencies are not abstract educational goals; they become practical requirements for making design decisions.

Brazil offers a particularly relevant setting for examining such collaboration. The country contains major environmental assets, including the Amazon biome, extensive freshwater systems, renewable-energy potential, biodiversity resources, and large urban-industrial systems. At the same time, Brazil faces persistent sustainability challenges related to deforestation, energy transition, water governance, urban infrastructure, waste management, agricultural production, environmental monitoring, and social inequality. Sustainable technology development in Brazil therefore frequently involves complex intersections between engineering innovation, environmental protection, data infrastructure, public regulation, private investment, and regional diversity. Projects in renewable energy, circular economy, precision agriculture, smart cities, sanitation, climate analytics, and biodiversity monitoring may require collaboration among professionals whose expertise is distributed across technical and environmental domains.

Despite the importance of such collaboration, empirical understanding remains limited regarding how engineers, data scientists, and environmental specialists experience collaborative work in sustainable technology development. Much of the existing literature emphasizes the promise of digital technologies, the principles of sustainability science, or the need for transdisciplinary research. Less attention has been given to the everyday collaborative practices through which professionals translate disciplinary languages, negotiate environmental and technical trade-offs, manage data, and integrate sustainability criteria into design decisions. Qualitative research is especially appropriate for examining these processes because it can capture meanings, tensions, and interactional dynamics that are not easily visible in quantitative indicators.

Accordingly, this study explores collaboration between engineers, data scientists, and environmental specialists in sustainable technology development in Brazil. The aim of the study is to identify the main collaborative processes, barriers, and enabling conditions through which interdisciplinary teams integrate technical, data-driven, and environmental expertise in sustainability-oriented technology projects.

## 2. Methods and Materials

This study employed a qualitative descriptive design to explore the experiences of engineers, data scientists, and environmental specialists involved in sustainable technology development projects in Brazil. A qualitative approach was selected because the research question focused on meanings, professional interpretations, collaborative practices, and perceived barriers rather than measurement of predetermined variables. The study was guided by an interpretive orientation, assuming that collaboration is shaped by professional norms, organizational contexts, disciplinary languages, and project-specific sustainability goals.

Participants were selected through purposive sampling. Inclusion criteria were: being professionally active in Brazil, having at least three years of experience in engineering, data science, environmental management, environmental science, sustainability consulting, or a related field, and having direct involvement in at least one sustainable technology development project. Sustainable technology projects included renewable-energy systems, environmental monitoring platforms, circular-economy technologies, water and sanitation technologies, climate analytics tools, smart-city systems, precision agriculture, and low-carbon industrial processes.

The final sample consisted of 27 participants. Nine participants were engineers, eight were data scientists, and ten were environmental specialists. Participants were recruited from private technology firms, environmental consultancies, public-private innovation projects, universities, start-ups, and sustainability units of industrial organizations. Recruitment continued until theoretical saturation was achieved. Saturation was reached at the twenty-fourth interview, when no substantially new themes were emerging, and three additional interviews were conducted to confirm the adequacy and stability of the thematic categories.

Data were collected through semi-structured interviews. Semi-structured interviews were chosen because they allowed the researcher to address core topics consistently while also giving participants space to describe concrete experiences, conflicts, interpretations, and examples. The interview guide included questions about participants' professional roles, experiences of interdisciplinary collaboration, project phases requiring collaboration, communication challenges, data-sharing practices, environmental evaluation, decision-making processes, tensions between technical and sustainability priorities, and recommendations for improving collaboration.

Examples of interview questions included: "Can you describe a sustainable technology project in which you worked with professionals from other disciplines?" "How did engineers, data scientists, and environmental specialists define the problem at the beginning of the project?" "What types of data or tools helped the team collaborate?" "What conflicts emerged between technical feasibility, data modeling, and environmental concerns?" and "What organizational conditions made collaboration easier or more difficult?"

Interviews were conducted in Portuguese and English according to participant preference. Most interviews were conducted online through secure video-conferencing platforms, while a smaller number were conducted face-to-face. Interviews lasted between 45 and 75 minutes. All interviews were audio-recorded with participant consent and transcribed verbatim. Field notes were written after each interview to document contextual observations, analytic impressions, and emerging concepts.

Data were analyzed using thematic analysis. The analysis followed an iterative process of familiarization, initial coding, theme development, theme review, theme definition, and manuscript reporting, consistent with Braun and Clarke's (2006) approach. NVivo software was used to organize transcripts, code segments, retrieve excerpts, compare codes across professional groups, and develop thematic matrices.

The analysis began with repeated reading of transcripts to identify meaningful units related to collaboration, communication, knowledge integration, sustainability criteria, data practices, and organizational conditions. Initial codes were generated inductively. Codes included, for example, "different meaning of sustainability," "engineering feasibility first," "data quality disputes," "environmental specialist brought in late," "dashboard as common language," "regulatory pressure," "trade-off negotiation," and "lack of shared metrics." Codes were then compared and grouped into broader categories. Through iterative refinement, five main categories were developed: shared sustainability problem framing, translation across disciplinary languages, data-mediated integration, negotiation of technical-environmental trade-offs, and organizational conditions for collaborative innovation.

To enhance trustworthiness, the analysis included peer debriefing, memo writing, code comparison across cases, and constant comparison among the three professional groups. A preliminary thematic structure was reviewed against the transcripts to ensure that the categories reflected the data. Representative quotations were selected to illustrate each category while preserving participant confidentiality. Participants were identified by professional group and participant number, such as Engineer 04, Data Scientist 11, and Environmental Specialist 20.

Participants received information about the purpose of the study, voluntary participation, confidentiality, and the right to withdraw before the interview. Informed consent was obtained from all participants. Identifying details were removed from transcripts, and participants were assigned codes. Data were stored securely and used only for research purposes. The study followed standard ethical principles for qualitative research involving professional participants.

## 3. Findings

The study included 27 professionals from Brazil. Nine participants were engineers, eight were data scientists, and ten were environmental specialists. Fifteen participants were male and twelve were female. Participants' ages ranged from 28 to 56 years, with a mean age of 37.4 years. Regarding education, five participants held bachelor's degrees, twelve held master's degrees, and ten held doctoral degrees. Professional experience ranged from 5 to 24 years. Eight participants had 5–10 years of experience, ten had 11–15 years, and nine had more than 15 years. Participants were involved in different sustainability-oriented sectors: renewable energy (n = 7), circular economy and waste management (n = 5), water and sanitation technologies (n = 5), environmental monitoring and precision agriculture (n = 4), smart cities and transport systems (n = 3), and ESG or climate analytics (n = 3). Participants were based in several Brazilian regions, including São Paulo (n = 9), Rio de Janeiro (n = 5), Minas Gerais (n = 4), Paraná (n = 3), Bahia (n = 3), Pernambuco (n = 2), and Amazonas (n = 1).

Participants emphasized that collaboration was most productive when the team jointly defined the sustainability problem before moving into technical design or data modeling. In less successful projects, each professional group entered the project with its own implicit definition of the problem: engineers focused on design feasibility, data scientists focused on prediction or optimization, and environmental specialists focused on ecological or regulatory risk. This created fragmented workstreams and late-stage conflicts. In contrast, effective teams began with shared problem-framing sessions in which members clarified the environmental objective, project boundaries, users, constraints, data needs, and expected sustainability outcomes. One engineer explained, "At the beginning, we thought the task was to build a more efficient system. The environmental team pushed us to ask efficient for what, and efficient at what environmental cost?" (Engineer 03). A data scientist similarly noted, "The model was only useful after we understood the environmental question. Before that, we were optimizing variables without knowing whether they mattered for the ecosystem" (Data Scientist 12). Environmental specialists described shared framing as essential because sustainability goals were often too broad unless translated into measurable but context-sensitive indicators. As one participant stated, "Everyone said the technology was sustainable, but we had to define whether that meant less water, fewer emissions, less waste, or lower risk to the surrounding community" (Environmental Specialist 19).

The second category concerned the continuous translation required among professional languages. Participants reported that engineers, data scientists, and environmental specialists often used the same terms differently. Terms such as "risk," "optimization," "impact," "efficiency," "validation," and "uncertainty" carried distinct meanings across disciplines. Engineers tended to interpret risk in terms of technical failure, safety, cost, and implementation constraints. Data scientists often associated risk with data quality, model error, bias, and prediction uncertainty. Environmental specialists connected risk to ecosystem disturbance, compliance failure, cumulative effects, and social legitimacy. These differences produced misunderstanding, especially when teams assumed that technical terms were self-evident. A data scientist commented, "When I said the model was accurate, the environmental specialist asked, accurate enough for what decision and for whom? That changed the conversation" (Data Scientist 10). Engineers described translation as a practical activity rather than a formal communication exercise. One engineer stated, "We needed someone in the room who could convert environmental restrictions into design parameters and also explain engineering constraints without making them sound like excuses" (Engineer 06). Environmental specialists also emphasized the importance of translation, noting that ecological knowledge had to be made actionable without being oversimplified. One explained, "Our role was not just to say yes or no. We had to translate environmental sensitivity into thresholds the design team could actually use" (Environmental Specialist 22).

Participants identified data tools, visual models, prototypes, dashboards, maps, and impact matrices as central mechanisms for collaboration. These artifacts helped professionals coordinate even when they retained different disciplinary perspectives. Data dashboards allowed engineers to see performance indicators, data scientists to evaluate model behavior, and environmental specialists to examine environmental implications. Geographic information systems, sensor outputs, life-cycle assessment summaries, and environmental risk matrices were especially useful when they connected technical design decisions to spatial or ecological consequences. One environmental specialist stated, “The map changed the discussion. Before the map, the wetland was an abstract concern. After the map, the engineers could see exactly where the design created pressure” (Environmental Specialist 18). A data scientist described the dashboard as a “negotiation space,” explaining, “The dashboard was not just a reporting tool. It became the place where we argued about what counted as success” (Data Scientist 14). Engineers also valued prototypes and simulation models because they made constraints visible. As one engineer noted, “Once we put the emissions estimate next to the energy performance curve, the trade-off became concrete. It was no longer one department against another” (Engineer 02). However, participants warned that data-mediated integration depended on data quality, shared access, and agreement on indicators. When data were fragmented, proprietary, or poorly documented, collaboration weakened.

The fourth category reflected the negotiation of trade-offs among technical performance, algorithmic efficiency, environmental responsibility, cost, time, and regulatory compliance. Participants rejected the idea that sustainable technology development was a simple process of adding environmental criteria to an existing technical project. Instead, they described sustainability as an ongoing negotiation in which teams had to decide which trade-offs were acceptable, which risks were non-negotiable, and which assumptions required redesign. Engineers often faced pressure to deliver scalable and cost-effective solutions, while environmental specialists challenged decisions that reduced environmental goals to minimum compliance. Data scientists were often positioned between these groups because algorithmic optimization could support either narrow efficiency or broader sustainability outcomes depending on how objective functions were defined. One engineer stated, “Sometimes the most sustainable option was not the easiest to build or the cheapest to maintain, so the real question was who had the authority to protect that option” (Engineer 08). A data scientist explained, “The algorithm will optimize what you ask it to optimize. If carbon, water, and biodiversity are not in the objective function, the model will ignore them” (Data Scientist 15). Environmental specialists emphasized that trade-off discussions had to occur early. One participant observed, “When environmental review happens at the end, sustainability becomes a correction. When it happens at the beginning, sustainability becomes a design principle” (Environmental Specialist 21).

The final category concerned organizational conditions that enabled or constrained collaboration. Participants reported that interdisciplinary collaboration improved when organizations created formal spaces for joint decision-making, allocated time for cross-disciplinary learning, established shared data protocols, involved environmental specialists early, and rewarded sustainability outcomes rather than only speed or technical performance. Conversely, collaboration was weakened by siloed departments, short project timelines, unclear authority, fragmented data ownership, and sustainability goals that were treated as branding rather than design requirements. One data scientist stated, "The company said sustainability was strategic, but the project indicators were delivery time and cost. That contradiction shaped every decision" (Data Scientist 11). Engineers noted that collaboration required management support because interdisciplinary work often slowed early project stages but prevented later redesign. An engineer explained, "The meetings felt slow at first, but they saved us from building something that would fail the environmental review later" (Engineer 05). Environmental specialists highlighted the need for legitimacy within the project team. One stated, "Collaboration worked when environmental knowledge had decision power. It did not work when we were invited only to approve what had already been decided" (Environmental Specialist 24). Overall, participants viewed collaboration as an organizational capability rather than a spontaneous outcome of assembling experts.

## 4. Discussion

This study explored collaboration between engineers, data scientists, and environmental specialists in sustainable technology development in Brazil. The findings showed that collaboration was shaped by five interrelated processes: shared sustainability problem framing, translation across disciplinary languages, data-mediated integration, negotiation of technical-environmental trade-offs, and organizational conditions for collaborative innovation. Together, these findings suggest that sustainable technology development is not simply the result of combining technical expertise from multiple professions. Rather, it depends on the capacity of teams to build shared meanings, translate disciplinary assumptions, create integrative artifacts, negotiate competing priorities, and institutionalize collaboration within organizational routines.

The first finding showed that shared sustainability problem framing was a foundation for effective collaboration. Participants described successful projects as those in which engineers, data scientists, and environmental specialists jointly clarified the environmental problem, the technological purpose, the project boundaries, and the criteria for success. This finding is consistent with sustainability science, which emphasizes that sustainability problems involve coupled relationships between social, technological, and ecological systems (Kates et al., 2001). It also aligns with Lang et al. (2012), who argued that transdisciplinary sustainability research requires collaborative problem framing to connect scientific knowledge with real-world problem contexts. In the present study, shared framing helped teams avoid narrow definitions of technology performance. Instead of assuming that efficiency or innovation automatically meant sustainability, participants emphasized the need to specify whether the intended benefit concerned emissions, water use, waste reduction, biodiversity protection, community risk, regulatory compliance, or system resilience. This supports Wiek et al.'s (2011) argument that sustainability work requires systems-thinking, anticipatory, normative, strategic, and interpersonal competencies. Shared framing helped teams activate these competencies by connecting technical choices to environmental values and future consequences.

The second finding concerned translation across disciplinary languages. Participants reported that collaboration was often hindered because different professional groups used the same words in different ways. Concepts such as risk, uncertainty, validation, optimization, and impact were not neutral; they reflected disciplinary histories and professional accountability structures. This finding is strongly aligned with research on knowledge boundaries. Carlile (2002) argued that knowledge boundaries in innovation require transfer, translation, and transformation. The present findings suggest that sustainable technology projects require all three. Transfer occurred when professionals exchanged information; translation occurred when they explained meanings across disciplinary contexts; transformation occurred when the team changed design choices or evaluative criteria because of interdisciplinary dialogue. Translation was especially important because environmental knowledge had to be converted into design-relevant thresholds, while engineering and data-science constraints had to be explained in ways that environmental specialists could evaluate. This finding indicates that collaboration depends not only on communication frequency but also on semantic and practical translation.

The third finding highlighted the importance of data-mediated integration and boundary objects. Participants described dashboards, prototypes, maps, life-cycle assessment summaries, environmental risk matrices, and simulation models as tools that helped professionals coordinate. This finding supports Star and Griesemer's (1989) concept of boundary objects: shared artifacts that enable cooperation among groups without requiring complete consensus. In this study, boundary objects allowed engineers, data scientists, and environmental specialists to see how their concerns intersected. For example, an emissions dashboard could connect engineering performance with data modeling and environmental impact. A spatial map could transform an environmental concern into a design constraint. A prototype could make trade-offs visible in material and operational terms. This finding also aligns with Cash et al.'s (2003) framework of salient, credible, and legitimate knowledge. Data tools became useful when they were credible to technical professionals, salient to project decisions, and legitimate from the perspective of environmental evaluation. However, participants also warned that data tools could not automatically integrate knowledge. Their value depended on data quality, shared access, indicator selection, and interpretive dialogue.

The fourth finding showed that sustainable technology development involves continuous negotiation of technical-environmental trade-offs. Participants emphasized that sustainability cannot be treated as a late-stage compliance label. Instead, sustainability must shape design criteria, data models, objective functions, material choices, and implementation strategies from the beginning. This finding aligns with Vinuesa et al. (2020), who showed that artificial intelligence can support sustainable development but may also inhibit sustainability targets if governance, equity, and accountability are neglected. It also supports Nishant et al. (2020), who argued that the value of AI for sustainability depends on its role in environmental governance rather than narrow technical optimization. The present findings extend this literature by showing how these issues appear in everyday collaboration. Data scientists noted that algorithms optimize the objectives they are given; therefore, if environmental indicators are excluded from model design, sustainability will remain external to technological performance. Engineers described tensions between feasibility, cost, scalability, and environmental ambition. Environmental specialists challenged teams to distinguish genuine environmental improvement from minimal compliance. These findings suggest that trade-off negotiation is not a barrier to sustainable technology development but a core mechanism through which sustainability becomes embedded in design.

The fifth finding identified organizational conditions as decisive for collaboration. Participants reported that collaboration improved when organizations created formal spaces for interdisciplinary decision-making, involved environmental specialists early, supported shared data governance, and aligned performance metrics with sustainability goals. This finding is consistent with team science research, which emphasizes that collaboration is shaped by contextual, organizational, institutional, and interpersonal factors (Stokols et al., 2008). It also corresponds with sustainability transition research, which argues that innovation for sustainability requires changes in institutions, practices, and evaluative systems rather than isolated technological solutions (Lang et al., 2012). In the present study, collaboration failed when organizations assembled experts but maintained siloed authority, fragmented data ownership, and project indicators focused only on cost and speed. Participants' accounts suggest that interdisciplinary collaboration must be designed into the organization. It requires time, legitimacy, incentives, leadership support, and decision rights. Without these conditions, environmental specialists may become late-stage reviewers, engineers may prioritize feasibility over ecological performance, and data scientists may build models disconnected from environmental realities.

A broader implication of the findings is that collaboration should be understood as a sustainability capability. The development of sustainable technologies depends on more than individual expertise. It requires collective capacity to integrate knowledge across epistemic, professional, and organizational boundaries. This finding contributes to the literature on sustainability competencies by showing how systems thinking, normative reflection, strategic action, and interpersonal competence appear in professional project settings (Wiek et al., 2011). It also contributes to the literature on digital sustainability by emphasizing that data-driven tools become sustainable only when embedded in collaborative and accountable processes (George et al., 2021). In Brazil, where sustainable technology projects may involve energy transition, water governance, biodiversity protection, circular economy, smart cities, and climate analytics, such collaborative capacity is particularly important. The findings suggest that Brazilian organizations working on sustainable technologies should invest not only in technical infrastructure but also in interdisciplinary routines that allow environmental criteria to shape design decisions.

The findings also reveal a tension between optimization and sustainability. Data science often promises optimization, but the object of optimization is socially and environmentally constructed. A model can optimize energy output, cost reduction, waste sorting, route efficiency, water distribution, or emissions reduction, but each objective reflects a decision about what matters. Participants' accounts suggest that environmental specialists play a critical role in challenging narrow optimization and expanding the definition of performance. Engineers play an equally important role in translating sustainability ambitions into feasible systems. Data scientists contribute by making complex relationships measurable, predictive, and visible. Collaboration becomes effective when these roles are mutually influential rather than sequential. In other words, the strongest sustainable technology projects are not those in which environmental specialists approve engineering designs or data scientists optimize predefined variables, but those in which all three groups shape the problem, model, design, and evaluation criteria together.

Another important implication concerns the timing of collaboration. Participants repeatedly stated that environmental input was most useful when included early. This supports the view that sustainability must be embedded in the front end of innovation, where problem definitions, design parameters, and data architectures are still flexible. Late-stage environmental assessment may identify risks, but it often has limited influence because technical and financial commitments have already been made. Early collaboration allows environmental indicators to become part of engineering requirements and data models. It also reduces the likelihood of costly redesign, regulatory conflict, or reputational harm. Therefore, sustainable technology development should be organized through iterative collaboration across the full project life cycle: problem framing, data collection, modeling, prototyping, environmental assessment, implementation, monitoring, and learning.

Finally, the study highlights the importance of power and legitimacy in interdisciplinary collaboration. Participants indicated that environmental knowledge was sometimes treated as secondary to engineering feasibility or commercial pressure. This finding is important because collaboration is not only a cognitive process but also an organizational and political process. Even when environmental specialists provide relevant knowledge, their influence depends on whether they have decision rights and whether sustainability indicators are included in project evaluation. Cash et al. (2003) argued that knowledge for sustainable development must be credible, salient, and legitimate. The present study suggests that legitimacy must also be internal to project governance. Environmental knowledge becomes influential when organizations give it authority in decisions, not merely when they invite environmental specialists to meetings. This has practical significance for sustainable technology firms, consultancies, innovation hubs, and public-private partnerships in Brazil and similar contexts.

This study has several limitations. First, the sample was limited to 27 professionals in Brazil and may not represent all sustainable technology sectors, regions, or organizational types. Although the sample included engineers, data scientists, and environmental specialists from diverse project areas, the findings may differ in sectors with stronger regulatory control, higher capital intensity, or greater community participation. Second, the study relied on self-reported interview data, which means that participants described collaboration from their own perspectives and may have emphasized certain successes or challenges while omitting others. Third, the study did not include direct observation of project meetings, design reviews, data-modeling sessions, or environmental assessment processes. Observational data could provide additional insight into how collaboration unfolds in real time. Fourth, the study focused on professional participants and did not include community stakeholders, policymakers, investors, or technology users, whose views may significantly shape the legitimacy and sustainability performance of technology projects.

Future research should examine interdisciplinary collaboration in sustainable technology development across different national contexts, sectors, and organizational forms. Comparative studies could explore whether collaboration differs between renewable energy, circular economy, water technologies, environmental monitoring, smart-city systems, and climate analytics. Longitudinal research would be especially valuable for understanding how collaboration changes from early problem framing to implementation and post-deployment evaluation. Future studies could also combine interviews with ethnographic observation, document analysis, and analysis of project artifacts such as dashboards, environmental reports, design specifications, and data-governance protocols. In addition, further research should examine the role of power, professional identity, and organizational incentives in determining whether environmental knowledge influences final design decisions. Studies including community stakeholders and regulators would also expand understanding of how sustainable technology projects gain or lose legitimacy beyond the project team.

Organizations developing sustainable technologies should create structured mechanisms for collaboration among engineers, data scientists, and environmental specialists from the earliest stages of a project. Project teams should begin with shared sustainability problem-framing workshops to define environmental objectives, indicators, boundaries, and decision criteria. Organizations should also develop shared data protocols, interdisciplinary dashboards, environmental risk matrices, and design review processes that function as boundary objects across professional groups. Environmental specialists should be given decision authority rather than being limited to late-stage approval roles. Data scientists should work with environmental experts to ensure that models include meaningful sustainability indicators, not only technical or financial variables. Engineers should be supported in translating environmental requirements into feasible design parameters. Finally, performance evaluation should reward sustainability outcomes, knowledge integration, and long-term environmental value, rather than only delivery speed, cost reduction, or technical novelty.

## 5. Conclusion

This qualitative study explored how engineers, data scientists, and environmental specialists collaborate in sustainable technology development in Brazil. The findings indicate that effective collaboration depends on shared sustainability problem framing, translation across disciplinary languages, data-mediated integration, negotiation of technical-environmental trade-offs, and supportive organizational conditions. The study shows that sustainable technology development is not achieved by simply assembling experts from different disciplines. It requires intentional processes through which different forms of knowledge are made mutually intelligible and influential in design decisions. Data tools, models, dashboards, prototypes, and environmental matrices can support this process when they function as boundary objects and are embedded in dialogue. However, collaboration is weakened when environmental knowledge is introduced late, when project indicators prioritize cost and speed over sustainability, or when data ownership and disciplinary authority remain fragmented. The study concludes that sustainable technology development should be understood as both a technical and collaborative achievement. Strengthening interdisciplinary collaboration can help organizations produce technologies that are feasible, data-informed, environmentally responsible, and socially legitimate.

## Ethical Considerations

All procedures performed in this study were under the ethical standards.


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## Conflict of Interest

The authors report no conflict of interest.

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