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Participatory convergence: Four cases for conducting convergent research using community-based approaches

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ABSTRACT

Convergence, as an approach to scientific inquiry, is designed to transcend disciplinary boundaries to solve complex real-world social, economic, and environmental problems. Despite initial scientific breakthroughs, early applications of convergent research provided little guidance for going beyond basic science and engineering to reach and engage impacted communities. To address this gap, we introduce *participatory convergence*, which combines the values and commitments of *participatory research* and *convergence research*, including listening to multiple voices to learn and comprehensively understand the scope of a problem while also working together across disciplinary boundaries and in partnership with communities to develop equitable, multi-faceted solutions. This article identifies seven core principles and offers a toolkit of techniques for advancing four phases of participatory convergence: alignment, co-production, implementation, and coordination. These principles and techniques emerged from an empirical comparison of four foundational socioecological projects in the Americas. Through these case studies, we illustrate the transformative potential of participatory convergence in advancing transdisciplinary science while addressing complex real-world challenges.

1. Introduction

Addressing grand challenges requires innovative approaches that integrate academic disciplines (Dietz, 2023). Convergence emerged as an interdisciplinary, problem-focused approach to solving society's most pressing needs (Roco and Bainbridge, 2003). Initially pioneered in engineering, nanotechnology, and biotechnology (Bainbridge and Roco, 2016), convergence is now widely used to address sustainability challenges (Roco, 2020), such as disasters (Lakhina et al., 2021; Peek et al., 2020), water (Misra et al., 2024; Roque et al., 2022), energy (Moran et al., 2022), landscape degradation (Devine et al., 2025), and resilience (Angeler et al., 2020; Sundstrom et al., 2023). In 2017, the National Science Foundation (NSF) identified "growing convergent research" as one of its 10 Big Ideas, leading to expanded global funding.

Convergent research emphasizes interdisciplinary collaboration to advance science and accelerate the application of findings (National

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Research Council, 2014; Roco and Bainbridge, 2003, Gajary et al., 2023; Peek and Guikema, 2021). By integrating natural sciences, engineering, social sciences, and humanities, it aims to solve complex problems and meet societal needs (NSF, 2019) and strengthen innovation through each member's unique perspectives (Gajary et al., 2023).

Despite its promise, early convergence provided limited guidance for converging *beyond* scientific disciplines to reach and equitably engage communities impacted by societal problems (Angeler et al., 2020). Yet, problem-solving requires innovations to be understood, accepted, and used by both researchers and communities (Hendricks et al., 2018; Meyer et al., 2018). Social scientists addressed this by integrating community engagement and ethics into the core of convergence (Devine et al., 2025; Moran et al., 2022; Peek, 2022; Peek et al., 2020). Building on these efforts, *participatory convergence* is a novel approach where convergence occurs across scientific disciplines, communities, and organizations committed to addressing urgent societal needs (Castro-Diaz et al., 2024; Roque et al., 2022).

Participatory convergence is both *participatory* (people-centered, equitable, ethical) and *convergent* (interdisciplinary, problem-focused, solutions-oriented). It requires communication and collaboration throughout the research lifecycle, emphasizing trust and mutually beneficial relationships (Castro-Diaz et al., 2024; Roque et al., 2022). It promotes fairness (Lembi et al., 2025) and reciprocity (Austin et al., 2024; West et al., 2021), prioritizing community agency and democratic implementation (Moran et al., 2022).

Although widely supported, the literature provides little guidance on applying participatory convergence principles in complex settings. To address this gap, we conduct a cross-case analysis of four participatory convergence projects and techniques to guide future community-based, transdisciplinary, problem-oriented, and solutions-driven projects.

2. Participatory convergence principles

Participatory convergence emphasizes the values of *participatory* and *convergence* research. This approach works across disciplinary and organizational boundaries, in partnership *with* communities, to develop equitable, multifaceted *solutions*.

In the late 1990s, the National Academies of Sciences, Engineering, and Medicine supported foundational reports on convergence, laying the groundwork for convergent research. However, despite focusing on complex socio-ecological problems they rarely involved social scientists (Peek et al., 2020). Over the past decade, social scientists have pioneered new approaches to convergence rooted in engaging community partners and aligning with societal interests (Brown et al., 2022; Devine et al., 2025; Lakhina et al., 2021; Misra et al., 2024; Moran et al., 2022; Peek, 2022). This article empirically develops the concept introduced by Roque and colleagues (2022) and the seven interrelated principles for participatory convergence (Castro-Diaz et al., 2024) (Fig. 1).

2.1. Overarching principles

2.1.1. Problem-focused and solutions-based

Participatory convergence must be *problem-focused* and *solutions-driven*, emphasizing rigorous approaches to urgent societal challenges (NSF, 2019). This focus distinguishes convergence research from interdisciplinarity and transdisciplinarity (Peek and Guikema, 2021). Participatory convergence moves beyond traditional convergence to foster close collaboration with local partners, enabling a deeper understanding of the problem and co-create fair solutions.

2.2. Research-oriented principles

2.2.1. Deep Integrated Research

Convergent teams must be interdisciplinary. Integration across disciplines, institutions, and career stages enables better understanding of complex problems and develop more robust solutions. Participatory convergence extends this by including diverse teams of researchers, including those with expertise in understanding systemic inequalities and using community-centered approaches (Peek, 2022).

2.2.2. Community engagement

Participatory convergence promotes sustained collaboration with communities, then rather than treating them as participants or end users, it engages them as co-creators in designing research, generating knowledge, and implementing interventions (Castro-Diaz et al., 2024; McGovern et al., 2024; Moran et al., 2022).

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2.2.3. Equitable and Just

This principle recognizes that many grand challenges are rooted in past and ongoing injustices. Participatory convergence seeks to co-create meaningful, relevant, and action-oriented projects addressing marginalized communities' needs, and enhancing local well-being (Moran et al., 2022).

2.3. Action-oriented principles

2.3.1. Action and reflection

Actions may include finding innovative ways to utilize new technologies, enhancing communication, establishing norms, collecting and analyzing data, or designing interventions. Incorporating reflection and self-awareness encourages the team to understand the importance of their own positionality and ethical commitments, fostering reciprocity and examining power dynamics (Austin et al., 2024; Bradbury, 2010; Evans et al., 2026; West et al., 2021).

2.3.2. Significant solutions

Participatory convergence projects aim to design substantively significant and contextually meaningful solutions to the communities they serve (Moran et al., 2022; Lembi et al., 2025). It emphasizes matching solution efforts to problem complexity through equal focus on research and co-development

2.3.3. Sustainable solutions

Sustainability requires long-term commitment and adaptability. Participatory convergence recognizes that there is rarely a "technical fix" for deep-rooted challenges (Peek et al., 2021). It promotes durable, trusting relationships, shared value creation, and collective agency that support ongoing collaboration (Austin et al., 2024; Gajary et al., 2023; Scoones et al., 2020; Shrum et al., 2007). Solutions must be locally led and implemented, possibly involving nurturing informal norms or new governance structures to support lasting change.

3. Foundational participatory convergence studies

In this section, we apply and elaborate on the principles introduced by Castro-Diaz and colleagues (2024) by analyzing four participatory convergence projects (Table 1). Cases were purposively selected based on the following criteria: (1) convergent research projects funded by NSF, (2) focused on socioecological research, (3) led by or with deep involvement from social and behavioral researchers; and (4) incorporated elements of participatory action research. Of the five collaborative projects initially identified and invited for participation, four agreed (One project declined due to political concerns and co-authorship processes for their case.) The data presented in this piece were drawn from the firsthand experiences and reflections of project participants and project dissemination materials.

3.1. Action for water equity

This project aims to address water insecurity in four U.S.-Mexico border states: Arizona, California, New Mexico, and Texas. It involves colonias, unincorporated territories facing challenges related to water, energy, transportation, housing, and food insecurity, along with structural disadvantages such as municipal underbounding, divestment, and racism (Wutich et al., 2022). The Action for Water Equity project focuses on closing the water access gaps in these communities and developing ethical collaboration with community partners; see Castro-Diaz et al. (2024) for an extended description.

3.1.1. Problem-Focused

Water insecurity is a significant issue in the U.S., where more than one million people lack access to clean, reliable water (Meehan et al., 2020; Roller et al., 2019). In such settings, water insecurity is disproportionately faced by vulnerable communities, such as disaster refugees, renters, mobile home residents, American Indians and First Nations, Black and Hispanic communities, and residents of colonias (Meehan et al., 2020a). Colonias experience various dimensions of water insecurity; many residents encounter barriers accessing safe, affordable, and reliable water services (Jepson, 2014; Zheng et al., 2022). Without formal water infrastructure, households rely on water hauling, private truck vendors, and bottled water (Wutich et al., 2022), facing ongoing challenges in keeping storage and collection containers sanitary (Jepson, 2014).

3.1.2. Deep integrated research

The team comprises experts in engineering, computer science, education, economics, law, policy, and social sciences from several U.S. universities, and at various educational levels. To facilitate communication between different disciplines, the project used various approaches, such as Value Propositions (Westerhoff et al., 2021), enabling teams to discuss project needs, approaches, and benefits from diverse perspectives and fostering a common language and understanding. The team also uses Natural Language Processing to analyze team discussions and track convergence by determining the semantic similarity between members' ideas (Li, 2020; Li et al., 2014).

3.1.3. Community engagement

Colonia residents and community-based organizations—the Rural Community Assistance Partnership (RCAP), the Rural Community Assistance Corporation (RCAC), and Community Unlimited— are project partners. The team developed an innovative ethnographic approach: Community-Based Participatory Observation (CBPO), in which local residents conducted participant observation (Roque et al., 2023) to better understand the water issues. Partners were engaged from the proposal development stage, helping shape the project through ongoing conversations and collaboration. Communities were selected with guidance from RCAP and RCAC, whose long-standing relationships supported culturally appropriate engagement (Castro-Diaz et al., 2024).

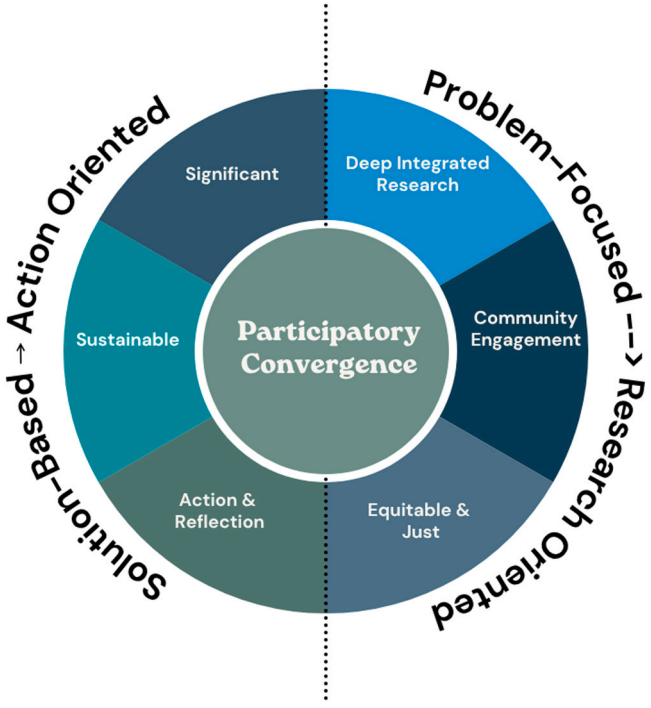


Fig. 1. Principles of Participatory Convergence (modified from Castro-Diaz et al., 2024).

3.1.4. Action and reflection

Regular meetings, training, and activities to facilitate feedback from team members and communities. This deepened the disciplinary integration, strengthened ties with local partners, and allowed team members to continually reevaluate their work. Additionally, they developed an educational module to instruct high-school students on measuring metals in water and demonstrate the effectiveness of water filters. The commitment to iterative action and reflection discussions helped the team better understand the problem, its causes, and potential solutions.

3.1.5. Significant, sustainable, and just solutions

The team is dedicated to working with community members to create sustainable solutions that address water insecurity. They use participatory convergence to develop equitable and sustainable solutions for water security, addressing local needs. Solutions could include installing water filters, using social networks to connect people, and developing modular, adaptive, and decentralized water and sanitation systems (Wutich et al., 2022; 2025).

3.1.6. Convergence for innovative energy solutions (Amazon energy)

This project originated from an NSF INFEWS grant investigating the impacts of hydroelectric dams in the Brazilian Amazon. The team found nearby communities lacked access to the dam-generated electricity, relying on polluting diesel generators that provided only four hours of power daily. To address this, supported by the NSF Growing Convergence Research grant, the team co-created environmentally, socially, and economically acceptable, just energy systems with communities.

3.1.7. Problem-focused

Across the Brazilian Amazon, one million households face the stark reality of lacking access to affordable, clean energy and remain unconnected to the centralized grid (MME, 2024). These communities face economic disadvantage and a lack of political clout, holding minimal sway in both public and private energy sectors. The challenges of extending transmission lines to these remote areas suggest a persistent off-grid status for the foreseeable future. This perpetuates a distressing cycle of poverty, inequality, and marginalization within these underserved communities (Moran et al., 2022).

3.1.8. Deep integrated research

This team includes collaborators from the Global North and the Global South, comprising engineers, social scientists, communicators, and journalists in various stages of their careers. Researchers from different colleges at Michigan State University partner with scholars at three Brazilian Universities: The State University of Campinas, the University of Brasilia, and the Federal University of the West of Para.

3.1.9. Community engagement

Community engagement is a core aspect of the project. From inception, the team worked with local communities to co-design and co-implement energy systems responding to their needs (Moran et al., 2022). The team used citizen science approaches, surveys, community meetings, and visioning workshops to discuss a desirable future characterized by increased energy access and effective governance of these systems. Training sessions on the installation and maintenance of technologies involved both men and women from the communities. These approaches, and the selection of communities based on their openness to collaboration, the extensive experience of the team working on the Amazon, and the ecological and technical conditions, are described in depth by Lembi et al. (2025).

3.1.10. Action and reflection

The team employed several approaches to engage residents in shaping the energy system, leading to cycles of action and reflection. A notable example is conducting workshops to gather both men's and women's perspectives, thereby ensuring a comprehensive

Table 1
Participatory Convergence Projects Overview.

Project	Overview
Action for Water Equity Goal: Build stronger connections between social and physical water infrastructure. Start Year: 2020 NSF Program: Growing Convergence Research (GCR) Website: https://azwaterinnovation.asu.edu/pillars/arizona-water-all	**Challenge**: Water insecurity in the Global North **Solution:** Modular, adaptive, decentralized water systems **Location/Region** U.S. border with Mexico **Converged Disciplines:** Anthropology + Engineering + Data Science + Hydrology + Law/Policy + Economics + Education **Participants:** Researchers + Community partners + Key informants + Local residents **Techniques for Participatory Convergence:** Value propositions, Community-Based Participatory Observation (CBPO)
Convergence for Innovative Energy Solutions (Amazon Energy) Goal: Co-develop clean energy solutions for off-the-grid communities in isolated regions of the Brazilian Amazon, minimizing the disruptions to their social-ecological systems while also avoiding the energy injustices of diesel generators. Start Year: 2020 NSF Program: Growing Convergence Research (GCR) Website: https://www.communitypowered.info/	**Challenge:** Energy access to off-the-grid communities **Solution:** Off-the-grid energy systems **Location/Region:** Off-the-grid communities in the Brazilian Amazon **Converged Disciplines:** Engineering + Journalism + Communication + Social Sciences **Participants:** Faculty members from U.S. and Brazilian Universities + Graduate and undergraduate students + Local residents + Local industry + NGOs **Techniques for Participatory Convergence:** Citizen science, Community workshops including showing animated videos of the technologies to be used, Visioning workshops, Training on the installation and maintenance of technologies, Final documentary video
ELEVATE (ELevating Equity VAlues in the Transition of the Energy System) Goal: Co-develop shared language on equity in the energy transition and apply it to technological change. Start Year: 2020 NSF Program: Global Venture (GVF); GCR Website: https://www.energytransitionumass.org/elevate	**Challenge:** Transition to renewable energy systems **Solution:** Build community capacity for just energy transitions by partnering with residents to co-design solutions **Location/Region:** Massachusetts; U.S. Virgin Islands **Converged Disciplines**: Engineering + Social Sciences + Policy + Computer Science + Humanities **Participants:** Researchers + Graduate students + Climate justice organizations + Local residents **Techniques for Participatory Convergence:** Game-based learning (GBL), Community-based participatory research (CBPR), co-designed workshops
CONVERGE: Coordinated Social Science, Engineering, and Interdisciplinary Extreme Events Reconnaissance Research Goal: Bring diverse teams and communities together to reduce the rising toll of disasters. Start Year: 2018 NSF Program: Formerly Humans, Disasters, and the Built Environment (HDBE) now Infrastructure Systems and People (ISP), Natural Hazards Engineering Research Infrastructure (NHERI) Website: https://converge.colorado.edu	**Challenge:** Rising disaster losses and disproportionate human suffering among society's most vulnerable populations **Solution:** Cultivate and train a diverse next generation of researchers committed to the principles of participatory convergence to ensure that problems are fully characterized and solutions are implemented that steadily reduce disaster harm **Location/Region**: A global network of researchers working in various sites at risk to various natural hazards and affected by disasters **Converged Disciplines:** Social Sciences + Engineering + Physical Sciences + Public Health **Participants:** Researchers + Policy makers + Emergency management practitioners + Local community

(*continued on next page*)

Table 1 (*continued*)

Project	Overview
	members + Graduate and undergraduate students **Techniques for Participatory Convergence:** Leadership Corps for integrating disciplines, interactive trainings focused on ethics and participatory methods, virtual forums, participatory convergence funding opportunities

understanding of gendered needs and desires related to the energy system. The visioning workshops depicted the collectively developed aspirations for how the energy system could work. This approach demanded a pragmatic assessment of their internal conditions like limited incomes, geographic isolation, and natural resources. Grounded in the community's reality, the project aimed to create an energy system that meets specific needs and improves well-being. Each community's vision resulted in different solutions, such as microgrids or individual solar panels.

3.1.11. *Significant, sustainable, and just solutions*

This project installed four energy systems with five more planned, tailored to community needs and ecological features. Hybrid systems using in-stream turbines and solar panels were implemented where feasible, with locally made turbines supporting maintenance and local industry. To ensure functionality and sustainability, the builder visited communities to understand their needs, community members were trained to maintain the systems, and governance processes were initiated, including a repair fund from small monthly contributions

A key part of the project was to demonstrate how participatory convergence supports communities, which reported that the systems improved their lives. To reach a wider audience, the project produced a documentary: "*The Forgotten: Sustainable Clean Energy for the Brazilian Amazon*[13]." The documentary shows the participatory convergence framework, emphasizing community involvement in co-designing energy systems. Its goal is to motivate communities to collaborate with researchers to design just solutions. It was an Official Selection at ECOCINE International Film Festival 2024.

3.2. *Elevating equity values in the transition of energy systems (ELEVATE)*

ELEVATE aims to transform local power systems from the household level to the transmission grid by using renewable energy and storage. The interdisciplinary team focuses on electrification, energy efficiency, and storage, emphasizing equity through community-based participatory research (CBPR) in Holyoke, Massachusetts. Holyoke, a post-industrial city, now faces disinvestment and environmental injustices. Despite producing electricity from hydropower, Holyoke still encounters energy issues, such as aging buildings that depend on gas or oil, which places a burden on residents. The team partnered with local organizations to promote a just transition, addressing housing, heating, and utility debts among low- and moderate-income and migrant households.

3.2.1. *Problem-focused*

Addressing society's urgent transition from a fossil fuel-dependent energy system to a sustainable one driven by renewable sources presents a paramount challenge. A low-carbon future relying on intermittent renewable energy sources like solar and wind power brings complex technical challenges when balancing electricity supply and demand. Concurrently, as the energy transition progresses, an equally important challenge is to ensure the inclusion of all communities—especially the most socially and economically marginalized—within this changing landscape. This project uses participatory convergence research to navigate the intersection of these technical challenges and social needs. Its goal is to develop and assess policies, markets, and algorithms aimed at creating a future electricity system that is both technically robust and socially equitable.

3.2.2. *Deep Integrated Research*

ELEVATE brings together researchers from diverse fields, including electrical, industrial, mechanical engineering, anthropology, economics, environmental science, and computer science. To unify scholars from different disciplines and career levels, ELEVATE adopted a game-based learning approach (Jan and Gaydos, 2016; Harper et al., 2018), developing team-building games focused on just energy transition strategies.

3.2.3. *Community engagement*

The community was chosen based on their existing relationship with a designated Environmental Justice Community in Massachusetts facing post-industrial economic decline. Trust was further built through regular presence at community events and urban gardening projects, where team members consistently interacted with residents. This ongoing engagement, along with legitimacy gained through collaboration with community groups, co-production of knowledge, and open bilateral communication with community organizers, strengthened the team's CBPR approach, which focuses on community needs. ELEVATE used methods like focus groups, participant observation, and game-based workshops to understand grassroots perceptions and engagement with energy transition issues (Harper et al., 2023).

3.2.4. *Action and reflection*

Insights from focus groups and workshops led the team, including community members, to initiate a follow-up project centered on Do It Yourself (DIY) workshops on home heating and indoor air quality. Participants learn to build window inserts and Corsi-Rosenthal air purifiers for shared spaces. These workshops promote community engagement with engineering students, exploring green buildings and renewable energy, their mechanisms, applications, and benefits. By connecting energy discussions to lived experiences through participatory methods, the DIY workshops address immediate issues and encourage dialogue about policy and systems. This cyclical process ensures that decisions are intentional, well-informed, and adaptable.

3.2.5. *Significant, sustainable, and just solutions*

Working closely with community members and partner organizations allowed the ELEVATE team to develop the Holyoke Community Energy Project, an ongoing CBPR collaboration. The Energy Justice Leaders program regularly gathers community members and the ELEVATE team for discussions and co-design sessions on residential electrification that do not displace environmental justice communities. In its first year, participants shared their experiences as low- and moderate-income residents, identified concerns, created a timeline of environmental justice changemakers in Holyoke, and co-designed an "Energy Futures Tour" to educate others about the evolving energy system. Graduates from the initial cohort assist in planning and conducting future workshops, helping to build local capacity for equitable energy policymaking.

3.3. *CONVERGE: coordinated social science, engineering, and interdisciplinary extreme events reconnaissance research*

CONVERGE fosters convergent research across multiple disciplines, focusing on natural hazards and disaster social science, engineering, public health, and physical sciences communities (Peek, 2022; Peek et al., 2020). Consequently, CONVERGE does not have a single research site, but connects global networks of researchers working in at-risk and

[13] https://vimeo.com/853909777

disaster-affected areas. Its core mission is to foster ethical, rigorous, convergent research addressing urgent social and environmental challenges.

3.3.1. Problem-focused

The intensifying effects of climate change, population growth in hazardous areas, economic inequality, and infrastructure decay amplify disaster frequency and severity, requiring communities to adapt and develop resilient strategies rather than seek a single solution (Peek et al., 2021). CONVERGE brings together interdisciplinary teams with community, practice, and policy partners to better understand the complex causes of risk and develop approaches to reduce harm and suffering from disasters.

3.3.2. Deep integrated research

CONVERGE hosts a Leadership Corps that serves as an umbrella for eight research coordination networks spanning disciplines and involving thousands of researchers worldwide. These networks enable communication, coordination, and collaboration during disasters. For example, the Structural Engineering Extreme Events Reconnaissance and the Social Science Extreme Events Research networks collaborate across disciplines during disasters. CONVERGE trains researchers before disasters occur to foster deeper integration and provides post-disaster funding for those committed to reciprocity, CBPR, and returning results to communities. This swift funding supports scientific progress while addressing urgent community needs.

3.3.3. Community engagement

CONVERGE resources are free and open to all researchers in hazards and disasters, promoting equitable access and diversity (Peek et al., 2020). They train researchers to collaborate with communities using culturally competent, participatory methods that prioritize local knowledge. These resources emphasize building trust through ethical practices like reciprocity, transparency, and ongoing engagement, including sharing findings and co-producing knowledge. They also help researchers understand how their positionality influences the research process. CONVERGE prepares researchers for emotionally challenging, ethical, and holistic work with diverse partners.

During the COVID-19 pandemic, CONVERGE held two major virtual forums that brought together hundreds of researchers and practitioners worldwide. In response, an open call for Working Groups was launched, which required teams to include members from three or more disciplines, and award recipients were asked to develop a community-grounded, convergent research agenda for their focus area. The 90 funded teams spanned five continents and involved more than 1100 researchers and local practitioners from various disciplines, organizational affiliations, and diverse racial and ethnic backgrounds.

3.3.4. Action and reflection

CONVERGE offers research check sheets and training modules to promote action-oriented, rigorous, and ethically grounded convergent research (Adams et al., 2023; Peek et al., 2021). The 50 + check sheets encourage engagement with lessons from experienced researchers. Modules feature active learning and self-reflection on issues such as collecting perishable data, working with vulnerable populations, and conducting emotionally and ethically grounded research. Each module includes interactive exercises and assignments, along with supplementary resources for future skill development, such as an annotated bibliography.

3.3.5. Significant, sustainable, and just solutions

To address rising disaster losses and disproportionate impacts on vulnerable populations, CONVERGE cultivates and trains researchers committed to participatory convergence, aiming to reduce losses and enhance collective well-being. From 2019–2026, over 17,000 unique users completed the Training Modules, including students, early-career researchers, government, non-profit, private-sector, media, and voluntary-sector workers. They come from different fields, including social sciences, emergency management, public health, engineering, and beyond (Adams et al., 2023). Evaluations demonstrate that early-career researchers and individuals from historically marginalized racial and gender backgrounds gain the most knowledge (Adams et al., 2022; Evans et al., 2021). Case studies highlight a commitment to just, contextually suitable solutions that reduce risks and save lives during natural hazards (Burlotos et al., 2020; Pollock and Wartman, 2020).

4. Toolkit: participatory convergence techniques

To advance participatory convergence as a community-centered approach, this section provides a toolkit with four technique types that foster inclusive, scalable, and sustainable solutions. These techniques support four participatory convergence stages: alignment, co-production, implementation, and coordination. Table 2 examines how each technique promotes participatory convergence.

4.1. Alignment

In the alignment stage, participatory convergence teams develop their basic conceptual understanding of the problem, create a shared language, share concerns, and agree on desirable and acceptable possible solutions.

4.1.1. Value propositions

The Action for Water and Equity team used Value Propositions to facilitate communication and build shared knowledge to solve social issues (Westerhoff et al., 2021). Members shared their understanding of the project: its needs, proposed solutions, benefits, and the effectiveness of their approach, enabling a discussion for peer feedback. This helped build knowledge, identify shared needs, refine concepts, overcome biases, and involve diverse stakeholders. An AI-enabled approach was developed for convergence analysis, showing enhanced convergence for the project (Li et al., 2026). While useful for clarifying ideas, this technique requires a skilled facilitator to avoid privileging dominant voices.

4.1.2. Game-Based Learning (GBL)

GBL helps teams learn about each other, develop communication and problem-solving skills, and build trust. ELEVATE used GBL principles to create team-building games that unite scholars at various career stages and promote convergence research. Games proved engaging and effective for understanding complex ideas, encouraging discussion, and strengthening team bonds. However, they can be time-consuming to design, participation varies, and without proper debriefing, the learning may not transfer to real-world research.

ELEVATE used games such as “Zapples to Zapples” and “Cards for a Just Transition” to make learning complex concepts enjoyable and effective. These games utilize the ‘judge and justify’ mechanic from Apples to Apples™ and Cards Against Humanity, where players choose cards that best match prompts related to equity and energy. The team also played “Power Grid,” a board game simulating an electricity market, followed by discussions on decarbonization, equitable markets, and energy demand. ELEVATE developed bilingual games on response strategies to avoid blackouts and led workshops to gather community input, emphasizing impacts on vulnerable groups and energy demand management. These games promote environmental equity discussions.

4.2. Co-production

In the co-production stage, participatory convergence teams create knowledge and potential solutions by bridging the stakeholder perspectives.

Table 2
Participatory Convergence Techniques.

Technique	Type	Promotes action	Scalable	Broadly inclusive	Considers power dynamics	Promotes engagement	Stimulates deep integration of disciplines	Promotes Convergence education and training	Facilitates cycles of action and reflection	Improves data quality	Time commitment	Technology needed
Value Proposition	Alignment	Yes, by clarifying needs and aligning solutions with tangible community benefits	It can be applied and adapted across different teams, projects, and contexts	It incorporate diverse perspectives through iterative team discussions		Possible, by creating spaces for all stakeholders to contribute and refine ideas	It requires teams to articulate and connect needs, approaches, and impacts across different fields	It builds skills in critical thinking, communication, and collaboration	Yes, allow sharing ideas and provide feedback from others.	It strengthens and validates proposed solutions	Some training & a facilitator is required; team members can train to facilitate	Can be conducted online. Team developed an AI online tool.
Games	Alignment	It helps participants understand complex challenges and encourages discussion and solution-oriented thinking	Games can be adapted and replicated.	It uses accessible formats it allows diverse perspectives	Yes, the games highlight impacts on vulnerable groups and encourage equitable perspectives through discussion	Its format open spaces for local communities to be active actors	Yes, promotes spaces for developing communication and problem-solving skills	It enables cross-disciplinary communication and collaboration at different career stages	Yes, through gameplay followed by structured discussions	It incorporates community knowledge and generates contextual data	Low time commitment for repurposing ready-made games; higher time commitment for designing new games.	Can be conducted online
Citizen Science	Co-production	It involves directly community actors in data collection and design of interventions	It can be replicated across communities focused on diverse topics	It involves local actors in meaningful roles, incorporate their knowledge and lived experiences	It promotes equitable collaboration among local actors, stakeholders and researchers	Yes, local actors are involved in hands-on data collection, decision-making	Yes, enables transdisciplinary research integrating research fields with local expertise	Yes, local actors	Yes, through continuous community feedback and adaptation	Yes, by incorporating real-time, locally informed observations and insights that enhance accuracy and relevance	Acknowledging local expertise. Requires time from local members to guide researchers	Tools depending on the research project. For instance GPS, tools for measuring water quality, etc.
CBPO	Co-production	Yes, by centering community members as co-researchers who leverage knowledge to address their own concerns	It can be adapted across multiple places	Yes, by bringing together stakeholders and residents at every stage of the research process	Yes, local residents act as observers, addressing power imbalances of conventional participant-observation	Yes, community participants are in agentive research roles as observers			It positions research as knowledge co-creation	Yes, by drawing on residents' lived experience and engagement, it produces contextually grounded data	High-time commitment to train data collectors	None required until data entry
Visioning Workshops	Implementation	Yes, open spaces for communities to envision and plan for a desired future	Yes, visioning exercises can be adapted and applied to different contexts	It engages local actors in defining priorities and needs		The workshops are collaborative and allows co-design processes			It encourages participants to envision futures, reflect on implications, and inform subsequent design decisions	It generates context-specific data about community needs, priorities, capabilities	Preparing for this requires a significant amount of time and commitment from local communities.	Can be conducted online
Training	Implementation	Yes, by equipping early career researchers	Yes, trainings are free and delivered online in a	Yes, by offering free resources that are	Yes, by teaching researchers to critically	Yes, by equipping researchers with practical	Yes, by providing shared concepts and methods that enable	Yes, by providing free trainings that promote convergence research across disciplines	Yes, the modules include knowledge	Yes, by promoting research that is ethical,	High time commitment in developing the trainings. The	Internet access and an email address for

(*continued on next page*)

Table 2 (*continued*)

Technique	Type	Promotes action	Scalable	Broadly inclusive	Considers power dynamics	Promotes engagement	Stimulates deep integration of disciplines	Promotes Convergence education and training	Facilitates cycles of action and reflection	Improves data quality	Time commitment	Technology needed
		and other professionals with practical, ethics-centered tools to conduct work that is directly responsive to societal challenges	self-paced environment that allows large and diverse audiences to engage with the materials	designed to help accelerate the training of diverse hazards and disaster researchers and practitioners	reflect on positionality and prioritize ethical and culturally competent research	skills in community-engaged methods and reciprocity	researchers from different fields to collaborate and address complex disaster challenges		checks, a final quiz, and interactive reflections and other exercises throughout.	culturally competent, reciprocal, and convergence-oriented	training modules take participants 30–60 min to complete.	registration are required.
Virtual Forums	Coordination	Yes, by directly connecting research to real-world needs and decision-making	Yes, by recording and sharing the virtual forums via the web, they engage a large number of participants at different times and locations	Yes, by enabling free online participation from individuals across geographic regions and from a wide range of institutions	Yes, by intentionally elevating community-impacted voices, creating space for equitable dialogue, and encouraging inclusive participation	Yes, by creating spaces where practitioners, community leaders, and researchers can identify research needs, ethical and safety concerns, and applied needs	Yes, by bringing together diverse experts in real time to exchange perspectives and collaborate	Yes, by exposing researchers to a cooperative—rather than competitive—environment where community-needs are centered and ethical concerns are given voice	Yes, the model adopted through these forums involves the possibility for all participants to either speak or to use the chat to share information and to respond to others	Yes, by promoting interdisciplinary collaboration, team formation, and data sharing	Virtual Forums are 60 min	Internet and Zoom access for real-time participation. Internet access to view recordings.

4.2.1. Citizen science

Citizen science involves stakeholders in data collection, democratizing science and building trust. In the Amazon Energy project, community members guided engineers to river sites for the installation of hydrokinetic turbines, learned to measure water speed, and shared seasonal river insights affecting turbine placement and local activities like fishing. For solar, residents helped with panel orientation, co-designed controls, monitored performance, and proposed system expansions. Although citizen science approaches are powerful, it is important that teams avoid perpetuating inequalities by overburdening community collaborators (Walker et al., 2021).

4.2.2. Community-Based Participant Observation (CBPO)

CBPO, developed by the Action for Water and Equity team, engages local residents in the research lifecycle. It fosters the co-production of knowledge through participant observation and community-based participatory research (Roque et al., 2023). In CBPO, local actors are participant-observers who record field notes and may also engage in later stages of analysis, interpretation, and publication. This approach leverages communities' existing strengths to understand and address their concerns (Roque et al., 2023). Although powerful, CBPO can be time- and resource-intensive, requiring significant effort to build trust and maintain participation.

4.3. Implementation

In the implementation stage, teams work to make imagined solutions a reality. Sometimes, this involves co-creating a new path forward; other times, it means supporting skill development and resources to help communities realize their vision.

4.3.1. Visioning workshops

The Amazon Energy team held Visioning Workshops, based on systems thinking, to explore future scenarios (Wiek and Iwaniec, 2014). Community members envisioned a reliable energy future, creating vision statements that outlined the benefits and consequences (Lembi et al., 2025). Communities prioritized community functions and household needs. These activities provided insights into community needs, values, and capabilities, prompting co-design discussions about governance, distribution, maintenance, and repair of the energy system (Moran et al., 2022).

4.3.2. Training

CONVERGE Training Modules are the first in the hazards and disaster field to synthesize entire bodies of knowledge and make this information freely available to community members (Adams et al., 2023; Peek et al., 2021). They focus on research ethics, methods, data, and the practical application of research to help address social problems (Adams et al., 2023). They are regularly accessed by students and early-career researchers, and by others new to the field.

The Amazon Energy project brought together members of Amazonian communities at a nearby university for 40 h of electrical training on installing and maintaining solar panels, before they helped with installations in their communities. They also learn to install and maintain hydrokinetic turbines if there's a stream with sufficient water flow to support this technology (Brown et al., 2022).

4.4. Coordination

In the coordination stage, teams scale and sustain participatory convergence solutions.

4.4.1. Virtual forums

CONVERGE Virtual Forums encourages researchers, funders, practitioners, and local people to share situational reports as a disaster unfolds. These forums have attracted hundreds of participants in large-scale disasters, like at the outset of the COVID-19 pandemic and after the 2025 Los Angeles Wildfires, to help identify pressing research needs, ethical challenges, and safety considerations. They are designed to encourage communication, coordination, cooperation, and collaboration while democratizing access to field research teams, data, and post-disaster funding (Peek et al., 2020). Before these forums, researchers often lacked effective ways to coordinate efforts or share data across contexts (Peek, 2022).

5. Cross-case comparison

Here, we report and reflect on our cross-case analysis of four participatory convergence cases. Our comparison focuses on each case's experiences with the seven principles and four sets of techniques for alignment, co-production, implementation, and coordination. Our findings highlight the importance of trust, iterative co-production, and structural constraints.

One key finding is the significance of trust. In all cases, success depended on early trust-building activities both within the research team and across the communities. These activities involved developing shared language and understanding problems and potential solutions. Amazon Energy co-defined project goals with local communities from the beginning. ELEVATE used game-based learning to build shared understanding. In Action for Water Equity, long-standing relationships and shared value propositions helped resolve conflicts. We find that trust-building and alignment are core to participatory convergence and to influencing success beyond the initial stages.

Another key finding is the central role of iterative knowledge co-production at every stage. Unlike traditional convergence, where interaction among scientific disciplines drives innovation, participatory convergence is driven by community knowledge that redefines and expands problem conceptualization, methods, and solutions. In Action for Water Equity, the colonias' preference for self-study—rather than being studied by outsiders—informed the development of the CBPO method. Community knowledge also guides and improves convergence solutions. Amazon Energy and ELEVATE exemplify this, where communities guided turbine placement in the Amazon and DIY heating systems in Massachusetts. Innovation ultimately results from cycles of action and reflection, like CONVERGE's post-disaster forums and training modules. Participatory convergence is an iterative process grounded in community knowledge, enabling a transdisciplinary approach to analysis and innovation.

A third key finding is that participatory convergence requires investment—funding, time, leadership, facilitation, and institutional support—to succeed. Primary barriers are not conceptual or methodological but stem from funding structures, timelines, and institutional incentives such as tenure criteria, which often misalign with participatory convergence work. Short funding periods obstruct the long-term trust-building process, while funding mechanisms that support universities but restrict disbursal to communities and partners can create participation barriers. The risk of participatory fatigue and incomplete projects rises when capacity-building, institutional support, and sustained funding are lacking.

We argue that systemic changes may be necessary to fully support participatory convergence, including adjustments to funding timelines and disbursal policies, tenure and promotion guidelines, and other institutional procedures. Training must also be expanded to equip more researchers to work with communities and across disciplinary boundaries. Even small shifts in these areas could significantly improve the performance of convergent projects and enhance the perception of academic research's value.

6. Participatory convergence future directions

Participatory convergence emphasizes working across disciplines and engaging with communities to better understand complex issues and

to develop and democratically implement equitable solutions. This article outlines seven principles and four sets of techniques to guide such work, developed empirically from a comparison of four foundational projects. The techniques presented reflect our experience, though others may be integrated into participatory convergence efforts. The choice of methods should be evaluated case by case, depending not only on the study's focus and research questions but also on project characteristics such as community priorities, existing relationships, desired levels of participation, and the interests and skills residents wish to develop.

The generalizability of our findings is limited by the comparison of four cases. Future research can contribute to this literature by expanding the number of global cases to (1) test and refine the principles and techniques, (2) contribute new cases and comparisons to further develop the participatory convergence approach, (3) conduct longitudinal studies on the long-term costs and benefits of methods, and (4) assess the impacts on teams, communities, and outcomes (Misra et al., 2024). Explicitly testing what works and what does not is essential for advancing this approach and ensuring just, sustainable solutions.

CRediT authorship contribution statement

Laura Castro-Diaz: Writing – original draft, Visualization, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Amber Wutich:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Lori Peek:** Writing – review & editing, Supervision, Project administration, Funding acquisition. **Rachel M. Adams:** Writing – review & editing, Investigation. **Maria Claudia Lopez:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition. **Emilio Moran:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition. **Ogechi Vivian Nwadiaru:** Writing – review & editing, Investigation. **Krista Harper:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition. **Action for Water Equity Consortium:** Writing – review & editing, Supervision, Project administration, Investigation, Funding acquisition. **Amazon Energy Consortium:** Writing – review & editing, Investigation, Funding acquisition. **ELEVATE Consortium:** Writing – review & editing, Project administration, Methodology, Investigation. **CONVERGE Consortium:** Writing – review & editing, Methodology, Investigation, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Data Availability

Data will be made available on request.

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