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AudaCITY: A Capacity-Building Research Method for Urban Sustainability Transformation

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The scale and urgency of sustainability problems the world over has led to calls for sustainability transformations in cities, regions, and countries. Such calls for transformation are underlain by a persistent knowledge-to-action gap between scientific knowledge production, policy, and practice. To rise to the challenges of sustainability and resilience, municipal administrators need to set evidence-based and ambitious sustainability targets and develop strategies to achieve them. Simultaneously, transdisciplinary sustainability science researchers need to generate scientific knowledge to further enable cities along pathways of transformation. This paper details a collaborative backcasting game, AudaCITY, developed to build transformative capacity in city administrations while also generating deep contextual knowledge to inform a transformative sustainability science research agenda. We present AudaCITY's key features, potential applications and adaptations, and exemplary outputs and outcomes for cities and researchers. We conclude with recommendations for adopting and adapting AudaCITY for use in action-oriented and transformational sustainability science and capacity building.

Keywords: cities, sustainability science, climate change, sustainability transformations, knowledge-action gap, serious games, urban governance

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INTRODUCTION

The scale and urgency of sustainability problems worldwide has leaders and groups across sectors calling for "transformation" and "transformative action," with explicit demands for structural transformations in socio-technical systems, cities, regions, and nations (Olsson et al., 2014; Wolfram et al., 2016; Abson et al., 2017). Such calls for transformation persist at the same time as knowledge of potential solutions to sustainability challenges accumulate, perpetuating a so-called "knowledge-to-action gap" between scientific knowledge production and policymaking (Van Kerkhoff and Lebel, 2006; Muñoz-Erickson, 2014; Rathwell et al., 2015; c.f., Matson et al., 2016). Complaints about the utility of sustainability science knowledge for decision making and action predate the establishment of the field (Funtowicz et al., 1998) and remain a recognized problem (Caniglia et al., 2020). Increasingly, sustainability science efforts draw from action research, living laboratory and other methods to real-world experimentation to simultaneously generate scientific knowledge and societal impact (c.f., Nevens et al., 2013; Schäpke et al., 2018). These methods all aim to close the knowledge-action gap by combining knowledge production with "real-world" action.

To contribute to these efforts, this paper outlines a "serious game" called AudaCITY, and the process of its development. AudaCITY is presented as a research and capacity-building method which closes the knowledge-to-action gap by simultaneously deepening scientific understanding of context-specific sustainability transformation (knowledge production) and building transformative capacity in city administrations (a "real-world" action). Transformative capacity is the capacity of individuals and groups to fundamentally alter the structure and function of systems toward more sustainable ends (Withycombe Keeler et al., 2018). The paper begins by elucidating the knowledge-action gap. Combining embedded sustainability science research with transformative capacity building is then introduced as a means of addressing this gap. The paper then outlines the motivations, background research and co-production process that generated AudaCITY, as well as the key steps in gameplay and what they offer researchers, in the form of knowledge produced, and city administrators, in the form of transformative capacity built. The authors provide reflections and critique from two rounds of AudaCITY gameplay, with the City of Tempe, Arizona, USA and the City of Portland, Oregon, USA. The article concludes with further recommendations for and challenges with intertwining development of transformative capacity building with deep case knowledge of city sustainability aspirations and challenges. AudaCITY is offered as a methodological advancement for further orienting sustainability research toward real-world transformation.

Urgency and the Need for Transformative Action

The challenges of climate change and response exemplify the insufficiencies of common modes of knowledge production to generate and mobilize around action-oriented science for sustainability that builds transformative capacity (McNie, 2007; Keeler et al., 2019a; Caniglia et al., 2020). In 2018, the International Panel on Climate Change asserted that worldwide carbon emissions must be curbed by 2030 in order to keep global warming within 1.5°C, thus averting some of the worst impacts of climate change (IPCC, 2018). Insufficient action to curb global greenhouse-gas emissions, however, now makes it likely that warming will exceed 1.5°C (IPCC, 2022), and significantly accelerated mitigation after 2030 will be required to keep warming below 2°C. Advancements in the science of climate change and the urgent please for action from scientists do not alleviate such constraints (see, for example, the American Association for the Advancement of Science initiatives "What we Know" https://whatweknow.aaas.org/ and "How we respond" https://howwerespond.aaas.org/) because they leave they system structure and the capacity of potential change agents untouched. While many public and private institutional actors in the U.S. possess power to make significant changes to fossil fuel emissions in the needed time frame, they face various perceived constraints on their ability and willingness to act. Progress is further slowed by a lack of national leadership on climate action. These constraints subsequently push responsibility for action to cities and the city administrations tasked with addressing climate change on the "front lines," as it were, while these same entities often face a lack of actor-centric and systemic transformative (Wolfram, 2016; Keeler et al., 2019a).

Practitioners themselves are beginning to demand more from the sustainability research community when it comes to generating action-oriented knowledge. The Urban Sustainability Directors Network (USDN), established in the United States to connect city sustainability practitioners, convened members from 28 cities in Summer 2018 to inform what was developing as the US National Science Foundations' largest funding opportunity for sustainability science: a Sustainable Urban Systems Research Network. These USDN professionals–charged with developing policies and programs to tackle not only climate change, but also issues ranging from food, water systems, and transportation to equity and inclusion in local governance–rely on actionable knowledge to carry out their work (Urban Sustainability Directors Network, 2020a). In the Summer 2018 meeting, participants made clear that sustainability science research has to better take into account the needs of sustainability practitioners if it is going to meaningfully contribute to sustainability transformation (Urban Sustainability Directors Network, 2020b). This includes the deeply contextual, and often non-transferable, knowledge of how and why sustainability action happens in specific communities. In September 2020, the National Science Foundation released the 2021 call for [what is now termed] the Sustainable Regional Systems Research Network, which places a strong emphasis on practitioner partnerships to facilitate the co-production of usable sustainability science (https://www.nsf.gov/pubs/2020/nsf20611/nsf20611.htm).

These calls for action-oriented research and the persistent challenges cities face in tackling sustainability issues reveal the need for new capacities, and therefore new research directions, to close persistent knowledge-action gaps and enable responses commensurate with the challenges at hand (Burch, 2010; Burch et al., 2014; Boehnke et al., 2019; Heikkinen et al., 2019). The emergence of long-term plans referencing climate change, or the growing presence of sustainability managers and directors within city administrations, point to important foundations. However, such municipal efforts are often grossly under or precariously funded; preempted by state government; under invested in transformative-capacity building across city departments; and struggling to focus attention on the particular needs of communities most at risk from climate change impacts (Ciplet and Harrison, 2019). A related challenge is that city staff historically come from esteemed professions in planning and law; areas fostering great technical acuity, but not necessarily expertise associated with systemic-futures thinking; inter and intra-generational equity; or participatory-based processes (Krumholz and Wortheim Hexter, 2019). Nor are city administrations necessarily incentivized to set transformational goals or court rapid change.

The above challenges cannot be set aside in the research process. Indeed, as Caniglia et al. (2020) state, "If we want to contribute to shaping change toward sustainability through research, we need to shift away from the assumption that

researchers should be separate from the processes of change that they investigate." Action-oriented sustainability science demands that researchers co-develop their questions and methods with practitioners in full knowledge of the strengths and limitations of the research context vis-a-vis sustainability goals. How cities address sustainability challenges is often related to current politics and political will, leading to a reliance on known and incremental solutions, rather than on novel and large-scale actions that accelerate progress on longer-term, system transformation (Bassett and Shandas, 2010). If action-oriented sustainability science is to be usable and transformational, researchers must develop a deep case-knowledge capable of revealing leverage points for transformation (Abson et al., 2017). This may include an accounting of: (i) how sustainability is understood and attempted in cities; (ii) a history of actions and relationships; (iii) political dynamics; (iv) socio-economic and geographic context; and (v) municipal assets ranging from infrastructure investments to the capacity of city administrators to rise to the call of sustainability goals. City-university partnerships that transcend single transdisciplinary project cycles, and focus on values and long-term goals, can support researcher-practitioner relationships that can perform such a regular and honest accounting (Caughman and Keeler, 2020).

Actor-Centric Transformative Capacity Building and Research

Practitioners and sustainability scientists alike need to change how they understand their role in sustainability transformation. City practitioners need to rapidly come to view themselves as change-agents empowered to shepherd transformational system change to address existential sustainability challenges (Stummer and Zuchi, 2010). For them, transformative capacity is the ability to design, test, and implement strategies to substantially improve the sustainability of their cities, informed by the values of the publics they represent (Bulkeley and Castán Broto, 2013; Chu, 2016). Sustainability scientists need to see themselves as essential players in transformation processes who, when not productively working in concert with practitioners, may potentially be siphoning away scarce resources (e.g., time; funding; good will) from the sustainability transformations they seek (Urban Sustainability Directors Network, 2020b).

Understanding and building actor-centric transformative-capacity (referred to simply as transformative capacity throughout this paper for brevity) is itself a research agenda (Keeler et al., 2019c; Wolfram, 2019). Keeler et al. (2019c) argue that sustainability practitioners have transformative capacity if they possess: (i) the sustainability competence to set audacious and evidence-based sustainability goals; (ii) the confidence to carry out actions with political risk to achieve sustainability goals (iii) the commitment to shepherd transformation over time; and (iv) the power to realize sustainability ambitions. Each of these determinants presents a set of research opportunities for sustainability science. **Table 1** provides definitions for the determinants of transformative capacity, as these are not made explicit in Keeler et al. (2019c), as well as examples of how transformative capacity manifests in city administrations, and the research opportunities offered by understanding and building each determinant. Knowledge of practitioner capacity to implement transformations and practitioner research needs are key leverage points for creating more sustainable futures in cities and are therefore critical for designing usable, action-oriented sustainability science research (Burch, 2010; Burch et al., 2014; Abson et al., 2017).

In light of the need for more integrated and transformational methods to sustainability, and a reframing of the roles of practitioner and researcher in sustainability transformations, the development of the AudaCITY method was guided by the following question: "How do you improve the capacity of researchers and practitioners to contribute to sustainability transformations in their shared communities?" In this frame, practitioners need transformative capacity; and researchers need better knowledge of their practitioner partners' capacity as well as that of the systems in which the research is embedded (Keeler et al., 2019c; Wolfram, 2019).

Game-Based Methods for Capacity Building and Actionable Foresight

Methods to build capacities of city administrators and policy actors more broadly include scenario planning (Selin, 2011; Keeler et al., 2019a), simulation modeling and gaming (Mayer, 2009), and policy exercises generally (Toth, 1995). Each set of methods comes with benefits and limitations. Where scenario planning may be used to support exploration of plausible futures, it may not necessarily yield actionable strategic outcomes as might, say, a business wargaming method (Schwarz et al., 2019). While gaming may yield immediately actionable outcomes, this may sometimes come at the expense of integrating dynamic and long-term views on alternative futures (Rumore et al., 2016). Where some methods successfully blend scenario activities and gaming, they may suffer a lack of integration with key decision-makers to enable uptake of action once capacity has been built (Vervoot, 2014, 2019). Responses to sustainability challenges like climate change require that individuals and organizations possess long-term visions of radically transformed systems that have tangible and actionable connections to the current state.

So-called "serious games" utilize the rules and structure of games and concept of play to allow "users" or "players" to test hypotheses, construct alternatives, and implement strategies, and they are increasingly used in sustainability science (Stanitsas et al., 2019). Like other futures methods, games face the challenge of tying individual-capacity building events to longer-term series of strategic action (Rumore et al., 2016). Gaming integrates the technical, physical, social, and political dimensions of a policy problem into a single space where alternatives and consequences can be explored for "policy-oriented learning" (Mayer, 2009, p. 852)[1]. Incorporating foresight in gaming enables capacity

[1] Mayer et al., 2004 define simulation gaming as "a simplification and condensation of the real system, allowing participants to experiment safely with (future) decisions and institutional designs and reflect on the outcomes (p. 314) They note that play often involves groups of people seeking to better "understand and manage" systems of which they are part (p. 314). They delineate as "open

TABLE 1 | Determinants of actor-centric transformative-capacity (Keeler et al., 2019c) with examples.

Determinant	Definition	Example from city administrations	Research opportunities
Competence	The knowledge, skills and attitudes that enable problem-solving within complex, long-term, contested problems. These include systems thinking, values thinking, futures thinking, strategic thinking and interpersonal competence (Wiek et al., 2011).	Planner recognizes that a new masterplan does not account for different climate change scenarios for their region. She conducts a scenario study and stress-tests the masterplan against alternative futures to support resilience in new developments.	Use of scientific information in city planning; knowledge domains integrated in sustainability planning; knowledge gaps critical to city activities.
Confidence	The attitude that one's actions can have the desired impact, both short-term and to the benefit of longer-term system transformation.	An energy program manager strongly believes that their efforts to develop and implement energy efficiency programs for low income communities will increase energy efficiency and affordability in those communities.	City practitioner self-efficacy; distance-to-target information; strategy needs; gaps in intervention efficacy or effectiveness research.
Commitment	Commitment is attitude over time. The willingness of an individual to pursue sustainability transformation within the organization regardless of failure and setbacks.	When a project to develop a local food hub to increase access to local foods fails, the local food coordinator begins a new project to create a food co-op that addresses some of the underlying issues with the food hub.	Resources for maintaining transformation; ongoing evaluation and assessment needs; opportunities for greater inclusion and scaling; values related to sustainability transformation.
Power	The ability to turn one's ideas and ambitions into reality; or as the future governance expert Carin Ism says, "the ability to materialize your will" (Ism, 2020).	Public works employee notices that contamination in recycling is reduced when recycle bins are placed in front of homes. She works with her manager and the deputy city-manager over several years to develop a pilot project to close an alleyway and move trash collection to the front of homes.	Intervention efficacy and effectiveness; meaningful metrics; network and power building.

building, often through the first-person exploration of divergent futures (Mayer et al., 2004). Games, in many ways, serve as boundary objects (Star, 2010) to facilitate learning in the context of larger, systemic, multi-actor change processes. Game-play fosters learning outcomes related to skill development, reflective consideration, and new practices resulting from new insights (Guston, 2001; after Lozano, 2014), particularly in complex systems (Alessi and Kopainsky, 2015). Critically for high-stakes, politically fraught conversations about climate change, as in the U.S., gaming and simulation activities also provide, "An opportunity to experiment in a safe, low-cost environment" (see also Crookall, 2011; Susskind and Rumore, 2013; Rumore et al., 2016, p. 746).

The experimentation and first-person perspective offered by serious games motivated the research team to consider developing one with and for city administrators. By experimenting with developing strategies for transforming their cities, it was imagined that city administrators could build their own transformative capacity. In particular they could see exactly how their professional responsibilities offered opportunities to contribute to longer term sustainability transformations. In addition, by playing a serious game about sustainability transformation with sustainability researchers, researchers could develop a critical understanding of challenges and opportunities for sustainability transformation. Schwarz et al. (2019) showcase how thoughtful and intentional combinations of multiple gaming, foresight, and simulation methods can prove particularly beneficial for many kinds of participants. The authors described a, "Prospective competitive strategy process" that provided players insight into factors affecting the business market; clarity around hidden and complicated systemic interactions; and practice with thinking about future dynamics and possible changes over time (Schwarz et al., 2019). AudaCITY was developed to leverage this potential by providing a structured environment, set of rules, and safe space for city administrators to deliberate about sustainability transformation in their municipalities. A review by Vervoot (2019) of the expansive history of games and foresight methods cites landscape planning (Bishop, 2011); marine spatial planning (Mayer et al., 2014); water system planning under conditions of climatic change (Valkering et al., 2012), and others as examples of areas where, properly tailored and executed with the appropriate and inclusive set of stakeholders, game, simulation, and scenario methods advance capacities related to a diversity of goals. While an exhaustive review is beyond the scope of the present article, the above survey demonstrates the motivation for developing the AudaCITY method as a serious game and that serious games can offer capacity-building to address climate change and sustainability challenges through research and practice (Hebinck et al., 2018; Vervoot, 2019).

AudaCITY GAME DESIGN AND CO-PRODUCTION

The AudaCITY game resulted from an iterative process of co-production (Lemos and Morehouse, 2005) which is increasingly used in sustainability science and, in particular, in city-university

games" those which have actual stakeholders playing and working through reality-based problems, with outcomes "not predefined but discovered during social interactions" (p 314 citing Duke, 2000).

collaborations (Trencher et al., 2017). In co-production, products and processes are the outcome of interactions between different types of actors (e.g., scientists and civil servants) and forms of social organization (e.g., science and city administration) (Muñoz-Erickson, 2014). To develop the game, the team followed the model of co-production in transdisciplinary sustainability science outlined by Lang et al. (2012), which includes three phases:

- Phase A: Problem Framing and Team Formation: The team included the sustainability director and one intern from the City of Tempe, Arizona, USA, and two faculty and one student from the School for the Future of Innovation in Society at Arizona State University. The process began with a challenge posed by the sustainability director: they wanted to provide city staff with the opportunity to consider transformational sustainability goals and how they might change the city.
- Phase B: Co-creation of solution-oriented transferable knowledge: The researchers created an outline for a board game that included the concept of a worldbuilding exercise focused on big sustainability goals and a guided backcasting activity to identify policies and programs. City staff reviewed the proposal and provided feedback. The game went through multiple iterations and the team regularly interacted with city staff from several city departments to enhance relevance, salience, and legitimacy of gameplay elements (Cash et al., 2003). Content for game components; Action Cards; and Challenge Cards were co-developed by team members ASU and the City of Tempe and included actual city portfolios of resources (e.g., by cooperatively deconstructing past city budgets to understand revenues and expenditure), strategic interests (e.g., by cooperatively reviewing the city's sustainability strategy), and previously experienced or current concerns. Through the game design process, we collaboratively refined a shared understanding of the goals of our city partner and our research team goals (**Table 2**).
- Phase C: Re-integration and application of created knowledge: A prototype of the game was played with 50 city staff from 6 departments at the City of Tempe, and 5 researchers and 10 graduate students from Arizona State University in August 2017. Game play took 3 h. Following game play, the team met to discuss insights and make changes to the game. The ASU researchers updated the game and presented a final report to the City of Tempe leadership. A revised facilitation guide used for gameplay in the City of Portland and including pictures of game cards is provided in the **Supplementary Material**. Insights from gameplay were further integrated into the City of Tempe's first Climate Action Plan.

TABLE 2 | City partner and university team goals, and shared elements and kinds of knowledge supporting actions for sustainability (Caniglia et al., 2020).

City partner goals	University research team goals	Shared elements and supporting knowledge
Aid the city's Strategic Management Office in working with departments to understand how individual departmental efforts align with holistic city priorities;	Investigate how capacity to implement sustainability and resilience plans and projects is distributed across city administrations;	Grounding in city operations; knowledge enabling contextual realization
Enable strategies to be revisited and enhanced over time;	Experiment with ways to adapt sustainability competencies to municipal planning and public service professionals;	Adopting a dynamic and reflexive approach; knowledge informing intentional design
Include a set of short questions, easily accessible to city staff, to support real-time futures and strategic thinking on department and city actions after gameplay.	Develop a transferable and evidence-informed means of imparting competencies and building transformational capacity among municipal staff.	Contributing to capacity building; knowledge enhancing shared agency

THE AudaCITY GAME

AudaCITY is a collaborative, backcasting game (Robinson, 2003). It is best played with six players per board, with one or more players acting as facilitator (reading instructions aloud, keeping time, keeping score). An outside facilitator can be used to aid gameplay. Multiple games can be played simultaneously with teams in friendly competition for high score. AudaCITY is set 25 years from the time of play. In the first of seven rounds of gameplay, detailed below and summarized in **Table 3**, players are informed that they are part of a team from a city being honored for its global leadership in sustainability. Before receiving a prestigious, international award for the sustainability transformation of their city, the team must elaborate the actions, small and large, that made the transformation possible. Vision elements, action prompts, and challenges are seeded by research on city plans, climate change, sustainability, and other fields. Over the course of gameplay, teams accumulate "Synergy Points" as demonstration of their ability to think about transformation from a systems perspective, guided by local values and national priorities, and considerate of a range of future scenarios. Outcomes of play include not only actionable vision and strategy elements but also various data on decision-making and interactions of interest to researchers studying and enacting actor-centric transformative capacity building or sustainability transitions (per **Table 2**, column "research team goals").

Round 1: Transformational Sustainability Goals

The first round sets the fictional and mechanical stage for the rest of the game. Players are informed of the 25-year leap into the future, and of their impending award. A player then randomly draws two "Transformational Sustainability Goal Cards" (**Figure 1**), which define the audacious goals their city has achieved. We selected the number two to introduce complexity without initially overwhelming players with interdependencies.

TABLE 3 | Overview of AudaCITY structure and desired learning outcomes for cities need, transformative capacity, and knowledge supporting actions for sustainability.

Audacity round	Player activity in round	Connection to city need	Transformative capacity built	Knowledge supporting actions for sustainability
1. Transformational sustainability goals	Discuss relationships among sustainability goals, city priorities, and interactions between the two goals flipped face-up	Familiarize cities with transformational sustainability goals (as opposed to goals that incrementally improve sustainability aspects of cities).	Competence: Values, systems; Collaborative	Prescriptive: knowledge to support alignment of intention with sustainable options
2. Ways of living	Specify sustainability vision to specific lifestyles, discussing interactions across lifestyles	Develop understanding of the systemic implications of transformational sustainability goals – how much change will have to occur in critical systems and the impact this has on peoples' lives.	Competence: Systems, futures, Collaborative	Generative: knowledge to deepen insight into system and system features of interest
3. Taking action	Scaffold envisioned lifestyles with actions flipped from an action deck; specify actions; coordinate overlapping actions; discuss action benefits for multiple envisioned lifestyles	Need to understand the range of catalytic actions available to cities to make progress on transformational sustainability goals, and how this has been done in other cities.	Competence: Strategic, systems; Collaborative. Confidence: Players gain experience building a transformational strategy and see how other cities have done the same.	Strategic: knowledge of possible ways to close the gap between intended, sustainable states and system features of interest
4. Facing a challenge	Reflect on the impact of an unexpected challenge on actions and the sustainability vision; adapt actions in response to challenge	Need to consider regularly consider the impact of low-to-medium probability events with high impact on city plans, policies and programs.	Competence: Futures, strategic, interpersonal. Confidence: Players gain experience develop contingency plans for their strategy.	Emergent: knowledge generated through exploratory iterations of alternative scenarios
5. Starting the transformation	Articulate three first steps each player can take to support up to three actions	City staff should see their actions today as part of, and essential to, longer-term transformation.	Competence: Strategic, interpersonal. Commitment: Players make commitments to aspects of the strategy that they can carry forward. Power: Players connect their actions to long term transformation.	Tactical: knowledge of how to specify gap-closing strategies in ways that fit to specific local contexts
6. Narrative writing	Rearticulate the arch of the city vision, the catalytic actions that enabled the realization of the vision, and the key first steps that will help make the vision a reality	Telling compelling stories about what a city has done and can do in the future is an important tool for bringing others along in the transformation.	Competence: Interpersonal	Situated: knowledge, whether strategic, generative, emergent, or otherwise, "tailored to specific contexts"
7. Scoring	Identify accumulation of synergy tokens as indication of sustainability thinking; consider plausibility of developed vision; commitment to first for real-world equivalent of actions proposed	Identifying and selecting from among more robust or adaptable ideas to advance city priorities; identifying and selecting ideas to further enhance through research or development.	Competence: All.	Empowering: knowledge supporting "actors to realize intentions in favor of new and alternative" practices Co-produced: knowledge resulting from "collective processes" with diverse groups

Transformative capacities referencing Keeler et al. (2019a). Kinds of knowledge paraphrasing or quoting Caniglia et al. (2020), ***Table 2****.*

The game includes 14 possible goal cards, drawing from Gibson (2006) seven principles for sustainability assessment. Each goal and short description are written in accessible language meant to challenge conventional sustainability goal setting in cities (John et al., 2015):

- A wise community, efficient with natural resources;
- A healthy community for people and the environment;
- A thriving community with opportunity for work and fulfillment;
- A just community for people today and tomorrow;
- An equitable and engaged community;
- An adaptable community, ready for many futures;
- An engaged community with broad participation.

As an example, the supporting text for "an adaptable community, ready for many futures" reads:

> *You are a future-sensitive city. Plans account for a variety of potential social and environmental shocks and include fully funded preparedness efforts. Residents are aware of their vulnerabilities and are capable of keeping their communities safe in the event of disaster.*

Players review the Goal Cards and place them in the center of the common play area (see **Supplementary Material**) and

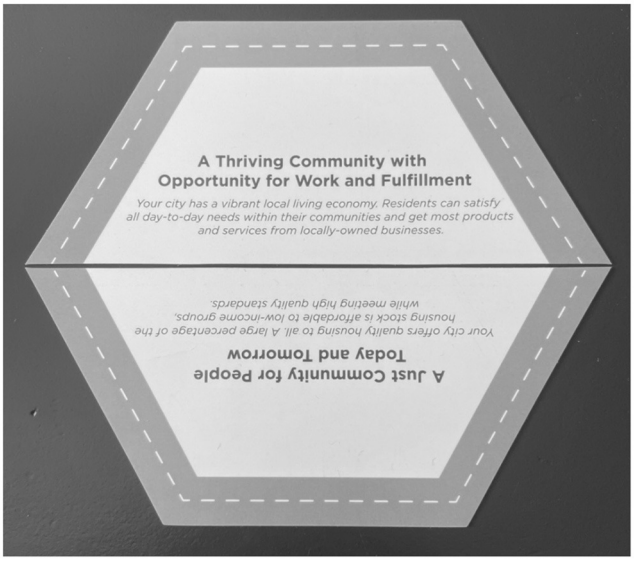

FIGURE 1 | Picture of two transformational sustainability goal cards.

are prompted to discuss synergies and tradeoffs between the goals and how sustainability goals have changed over the last 25 years. They are also invited to link the sustainability goals with existing goals or priorities at the city. If the group is able to link a sustainability goal with one or more existing city goals, they may place a Synergy Token on the board. Synergy Tokens are used throughout the game to reward thinking in terms of multiple, reinforcing gains, key to normative thinking in sustainability (Wiek et al., 2011). The round is further designed to foster normative thinking by familiarizing players with transformational sustainability goals and guiding them to consider how those relate to other reference-city priorities. An example research opportunity in round 1 relates to uncovering how city actors view sustainability goals from respective departmental perspectives, which can be prompted by the facilitator probing questions and observation of responses.

Round 2: Ways of Living

After establishing a shared understanding of "big-picture" goals, each of six players randomly draws one of eight "Lifestyle Cards" (**Figure 2**). Each Lifestyle Card describes one way in which people utilize and inhabit cities. Lifestyle Cards are framed to foreground persons' experience of cities, with secondary consideration for the systems that support those activities. They are derived from Brundiers's (2016) research on developing capacity for sustainability transitions in post-disaster recovery situations, which emphasizes the benefit of staying close to people's lifestyles when developing plans and scenarios. The Lifestyle deck includes cards for Working, Housing, Moving, Eating, Educating, Recreating, Shopping, and Communicating.

As with each Transformational Sustainability Goal card, each Lifestyle Card includes three to four specifying sentences for players. For example, the supporting text for "Moving" reads:

Aspects of life related to moving within and beyond the city. Consider why people move, for how long, and by what means. Consider modes of transportation (e.g., public, bike, foot), infrastructure like roads, rails, and stations, as well as businesses and networks (e.g., car-sharing or ride-hailing).

The cards guide players in elaborating a richly imagined future city transformed by sustainability goals and the efforts of audacious residents, elected leaders, and city administrators. Once they have received their cards, players take a few minutes to write how lifestyles have been transformed in achievement of the sustainability goals in play. Each player shares their specified Lifestyle Card with the group and places it on the board adjacent to a transformational sustainability goal. As a group, players identify systemic connections and interactions across Lifestyle vision elements. If a player can identify a connection between their Lifestyle Card and another, they place a Synergy Token on the card to denote a systemic vision element.

Round 2 is designed to develop values thinking and strategic thinking competencies (see Wiek et al., 2011 for an elaboration of sustainability competencies). Values thinking is developed as players consider what transformational sustainability goals mean city operation. Sustainability goals require systemic transformation, and many will have significant implications for how people live their lives. This round familiarizes players with the sorts of transformations required to realize sustainability goals. Players build systems-thinking competence by identifying the systemic transformations that their city will undergo and by linking transformations across domains of society. An example research opportunity in round 2 relates to identifying ways that sustainability goals may be salient to city staff, as well as lifestyles proving less amenable to alignment with sustainability goals.

Round 3: Taking Action

With a detailed and systemic picture of how their city has been transformed 25 years in the future, the team begins working to develop the strategy that helped them achieve that vision. The action phase is designed to unfold collaboratively and quickly, moving backward from the vision to the present. Each player draws one of fifteen "Action Cards" describing a generic municipal government action (**Figure 3**). One by one, players: describe how their action could contribute to the transformations described on a Lifestyle Card or the action described on another Action Card: summarize this contribution on the card; and place it adjacent to the card it supports or builds upon. Unsupported Lifestyle sectors merit a point penalty, while explicitly linked Actions earn a Synergy Token bonus, incentivizing Action coordination. The goal for this round is to support with actions as many of the Lifestyle Cards as possible, and to combine actions to create a synergistic strategy. Placement of actions continues for the entire 15-min time limit of the round.

Action Cards represent a mix of projects, programs, and policy tools available to cities and in use by a diverse array of city governments. Real-world examples accompany each action, supported by extensive research into diverse city plans, programs,

FIGURE 2 | Lifestyle cards surrounding two transformative sustainability goal cards **(left)** and a close up of the moving card **(right)**.

ordinance, practices, etc. The following actions are included in the AudaCITY 15-card action deck:

Changing zoning code	Implementing a new tax
Creating a new city organizational structure	Making a catalytic infrastructure investment
Implementing a strategic planning initiative	Instituting a new bond
Receiving a grant award	Reforming procurement
Developing a public-private partnership	Planning human resources investments
Engaging the public	Training in technical skills
Leveraging media	Reforming administrative process
Incubating innovation	

The text for the "Reforming Administrative Processes" card, including real-world example, follows:

> Modify city decision, budgeting, and review processes within and across departments, to better serve your sustainability goals. *Example: Fort Collins, CO evaluates all policies according to a sustainability checklist.*

Rules for this round further encourage strategic thinking. Players must identify what actions their city can take and how those actions work together to enable larger scale transformation. Points are awarded for multi-action strategies and points are deducted for any Lifestyle Cards left unsupported by actions. Noting, over successive instances of implementing AudaCITY, neglected actions, frequent strategies, creative solutions, and other features of participant responses offers a rich source for research into city strategy development for sustainability. For researchers, the round reveals how practitioners think about the plausibility and desirability of different courses of action. These actions can be supported by different kinds of research activities.

In this round, players build strategic competence in several ways. First, they become familiar with the variety of different tools available to cities to take action on sustainability goals. Second, they practice considering how their city could adapt such tools to achieve the sustainability goals they've identified. Third, they link actions together to create greater impact. Finally, they are reminded of the impact of creating vision elements unsupported by actions – the game penalizes stranded vision elements because city visions unsupported by city action do not become reality (John et al., 2015).

Round 4: Facing a Challenge

With a completed vision and strategy, the team draws a "Challenge Card" (**Figure 4**). Challenge Cards are designed to promote consideration of foreseeable and unforeseeable events likely to occur along any path to sustainability transformation. Their responsibility in this round is to determine how their strategy was impacted by the onset of said challenge and what, if any, adaptations they were able to make to permit continued progress toward their vision. The following actions are included in the AudaCITY 10-card challenge deck:

100-year storm	Heat wave
Civic unrest	New state or federal mandate
Lawsuit	Initial plan failure
Dark money campaign opposition	Uncertainty about future climate impacts
Internal process setback	Recession

Each Challenge Card contains a detailed elaboration of the challenge scenario. For example, the text for "new state or federal mandate" shares:

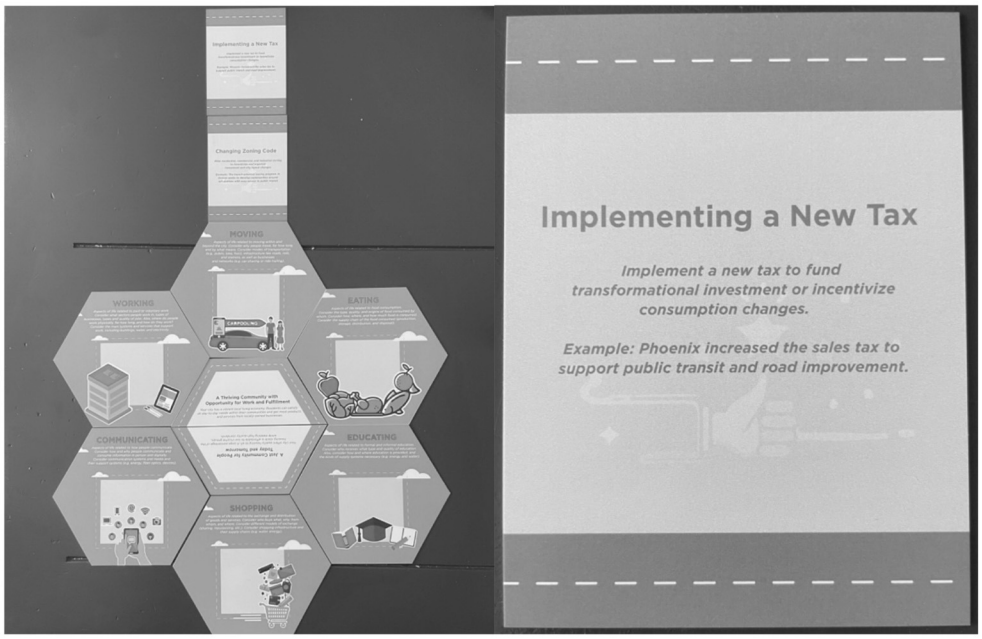

FIGURE 3 | Action cards building on lifestyle cards **(left)** and close up of the implementing a new tax card **(right)**.

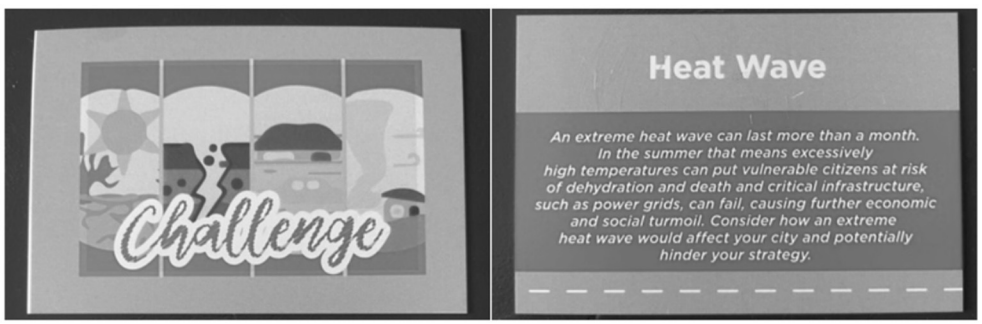

FIGURE 4 | Front and back of a challenge card.

> Federal and state governments can react negatively when cities are perceived as carrying out their own agendas. This happens to your city. A law is handed down that affects your ability to implement actions to achieve your sustainability goals. Consider the politics of your region and what kind of law or mandate might be imposed?

Players identify actions affected by the challenge and place a "Challenge Token" on actions deemed no longer viable. Challenge Tokens count against the total score. If the team is able to determine an adaptation to a potentially impacted action, no challenge token is placed.

In this round, practitioners and researchers alike develop their capacity to contribute to strategies that are resilient to a variety of social, political, environmental, and economic circumstances. The round develops players' futures thinking competence by encouraging consideration of future shocks on sustainability strategies. They further develop their strategic competence by conceiving adaptations for actions as challenging circumstances arise. Documentation of these discussions provides qualitative data (of interest to researchers and practitioners alike) which may point to systemic vulnerabilities; fragile transition pathways or actions; particularly thorny challenges that could benefit from research collaboration; and creative adaptations.

Round 5: Starting the Transformation

In the final round of play, each player receives a blank "First Step Card" and must identify present-day actions by which they, in their actual role, could initiate the sustainability transformation captured by the board. Players complete cards individually and then share with their team. As a group, the team discusses how each of their first steps support the action, strategy, and transformation outlined by AudaCITY. Before ending the round,

FIGURE 5 | Completed gameboard (taken during game play in the city of Portland).

players commit to taking post-play responsibility for as many first actions as they are willing. The team receives points for every first step accounted for by a committed player. For every uncommitted first step, a point is deducted.

The final round builds strategic competence by guiding players in linking their current job responsibilities with the transformations outlined on the board. Additionally, the round builds another critical determinant of transformational capacity: commitment, expressed positively to colleagues during gameplay. Aggregating the first steps associated with different departments, actions, and lifestyles can point the way to research needed in the immediate term to substantiate action in the present; specifically, identifying how current-state constraints inhibit transformative pathways.

Round 6: Telling the Transformation Story

The final activity of gameplay re-affirms the overall narrative vision, catalytic strategy, and key first steps of the transformation. **Figure 5** depicts a completed game board that forms the basis of the Transformation Story. It is a chance for the players to return to the initial invitation of play and share the story of their city's transformation.

In this round, each table develops a short story about how their city became world-renowned for sustainability. This narrative product can be shared beyond the game to spark discussion of how transformation might be pursued in their own, actual city. To facilitate narrative creation in a timely manner, players are asked to:

- Create a compelling title for their vision;
- Describe a day in the life of a local resident 25 years in the future, to give a sense of how the city looks, feels, functions, smells, etc.;
- Highlight key catalytic actions—a few critical efforts to the transformation that took place;
- Point to a few of the exciting first steps the players take at the beginning of the sustainability transformation journey to help the transformation get underway.

Narratives communicate complexity and narrative development builds capacity to make systemic linkages (Luederitz et al., 2017). Both researchers and practitioners learn more about the sustainability potential of the city and transformation options by engaging in this synthetic step. By reviewing their vision and strategy, players have another chance to create ownership over the transformation.

Round 7: Scoring

Once gameplay is complete, a group calculates its total score. Throughout play, when players discussed coordinated action and alignment of sustainability goals, lifestyle elements, and actions, they received Synergy Tokens worth one point each. Synergy Tokens were conceived to reward the use of sustainability-linked ways of thinking and building commitment to transformation. To further emphasize these desired outcomes of play, the scoring round penalizes the team for leaving vision elements unsupported or challenges unaddressed. Vision elements without supporting Action Cards; Action Cards without supporting first-steps; and unaddressed Challenge Tokens each inflict point deductions. Finally, the table has a chance to vote on the plausibility of their vision and strategy.

Initial Reflections From Gameplay

AudaCITY is designed to be tailored to specific city environments, based on existing local, regional, and national priorities, strategies, and policies. To date, the game has been tested in the reported format in two city-specific training workshops with the cities of Tempe, Arizona, USA and Portland, Oregon, USA; and in adapted forms on the Navajo Nation and in Luneburg, Germany. Brief reflections from gameplay in Tempe, a city early in its work toward sustainability thinking and practice, and Portland, a city with a longer history of sustainability thinking and practice, follow.

In the City of Tempe, AudaCITY was piloted to build staff capacity across the municipal government to set transformational sustainability goals and envision ways that those sustainability goals connect to current city activities and priorities. The game was played simultaneously with six groups of six department heads or project managers. Faculty and graduate students from Arizona State University acted as facilitators and notetakers. For faculty, the game presented an opportunity to inflect city discussions of sustainability objectives with insights from their research and to identify new opportunities for research collaboration. For students, it was an opportunity to gain deep contextual knowledge of the city many of them would be conducting thesis work with. At the time of play, the city was preparing for its first climate action planning process. Playing AudaCITY was intended to spark ambitious, creative idea generation, as well as enthusiasm for a new kind of sustainability-oriented planning requiring broad buy-in across

the city. The university researchers were able to leverage their expertise in sustainability to reinforce learning objectives in the game and to steer conversations toward evidence-based goals and actions. Researchers participating in the game play gained an understanding of what sustainability goals and actions city administrators see as plausible, and where enthusiasm lies for particular projects which could benefit from university collaboration.

Gameplay with the City of Tempe helped groups of players forge shared ownership around efforts that have since been carried forward by key city players. Conversations emerging around resilience to extreme heat, energy resilience, and transportation have grown into ongoing transdisciplinary research projects between the city and university and have since been incorporated into Tempe's first ever Climate Action Plan. Most significantly, the city had a 20% municipal renewable energy policy adopted in 2014, prior to game play, and following gameplay adopted a new 100% renewable energy goal as part of the climate action plan (Keeler et al., 2019b). Beyond the Climate Action Plan, the city adopted "Vision Zero," a city-wide goal to eliminate traffic fatalities.

In Portland, the City wanted to use the game to spark more cross-bureau collaboration on green infrastructure development. The game was played with Portland's green infrastructure working group, convened by Portland State University's Institute for Sustainability (ISS) solutions deputy director and including six department heads or project leads from multiple bureaus. Portland's ambition was to expand its vision for how transformational sustainability goal setting could infuse bureau- and office-wide, comprehensive green infrastructure planning. The Institute for Sustainability Solutions (ISS) at Portland State University facilitates city-university collaboration for the city. The game surfaced areas where ISS could develop collaborative, applied research projects to serve the city's green infrastructure vision. Research from a faculty at Portland State University was referenced several times during game play as providing an important evidence base for future green infrastructure projects. The game revealed the kind of knowledge the city needs as well as its existing expertise, both of which provide important case context for the development of actionable, transformative sustainability science projects.

In Tempe and Portland, active facilitation proved instrumental to surfacing creative, audacious, concrete, and systemic visions of transformational sustainability goals. In Portland, the added fact of the facilitation teams' being "outsiders" (i.e., from Arizona State University) helped to push the Portland group to seek clarity and to foreground latent but critical questions requiring cross-bureau attention. By intentionally inviting cross-bureau participation, gameplay opened up a useful space for developing systemic visions acknowledging a fuller complexity of sustainability transitions in urban settings.

Our experiences to date suggest that what happens after gameplay is equally vital to reflect on. A post-game report to players does not do justice to the depth and breadth of planning actions and issues uncovered in AudaCITY play. Our experiences revealed the importance of having clear ways for players to leverage the experiences of gameplay in subsequent department meeting or planning efforts. For researchers, there were many follow up discussions and projects after AudaCITY. For example, discussions from the AudaCITY game led directly to a second workshop on the future of sustainable food in Tempe. Graduate students adapted the AudaCITY game to focus on sustainable local food economies in response to enthusiasm and need expressed during the game play. Furthermore, game play surfaced many questions and much interest about energy efficiency and carbon emissions reduction possibilities at the City of Tempe. This informed a subsequent research project to inventory to analyze existing carbon emissions reduction activities and practitioner perceptions of further opportunities, including interviews with 42 city staff. Results of that research informed the City of Tempe's first Climate Action Plan, passed by city council in Fall 2019. Further research is needed to quantify the impact of the game play on these relationships and on the sustainability outcomes generated by subsequent collaborations.

DISCUSSION

Below, we discuss several insights from early-stage AudaCITY gameplay for refinement and improvement. These improvements relate, generally, to game design and data collection; facilitation; and pre- and post-session preparation.

Real-time data capture—in terms of the substance and nature of table discussions—is a challenge with this type of method. During gameplay in Tempe, participants documented responses on sticky notes. In Portland, this was addressed with worksheets, and having players take turns documenting discussions of the group. This latter method of data capture aided in follow up with players by researchers and the long-term use of those qualitative results for research and partnership development activities.

AudaCITY depends on knowledgeable, confident, and disciplined facilitators. This is consistent with findings from other participatory futures methods including scenarios and serious games (Keeler et al., 2019a). Researchers can perform the role of facilitator if they are experienced. Such arrangements provide researchers with insight into city administrators' responses to game conditions, as well as emergent knowledge needs or research opportunities, and offer an opportunity to socialize and build rapport. This dependence has implications for ways that facilitators might undesirably influence the process of gameplay. Transdisciplinary principles of co-production must be upheld by researchers during facilitation. An agenda-driven facilitator can unwittingly (or wittingly) change the character of a table conversation by imposing his or her wishes, consequently leading to deterioration of authentic play experience, which limits research insights and compromises capacity building. Conversely, a facilitator who fails to assert their legitimate expertise and authority on the AudaCITY game might also diminish player experience. The totality of expected outcomes of gameplay thus depend on competent, researcher-facilitators. In this regard, AudaCITY is more facilitator-dependent than other serious games and while this might have research benefits, it

may also impede the immersive and experiential aspect of games generally, which contributes to their utility for capacity building.

While transformational capacity building was central to game design, we found an ancillary benefit of AudaCITY in cultivating awareness of the larger social support available for new initiatives by cities. Researchers can augment discussions during the AudaCITY game with best practices from their research, but this does further reinforce the central role of the facilitator. To this end, we found it important to bolster individual city staff capacity with collective awareness of sustainability planning as a movement; for instance, Action Cards, drew examples from cities other than those most lauded for sustainability transformations (e.g., not San Francisco, California or Portland, Oregon). Game materials drew from cities small and large, affluent and resource-limited, conservative and liberal alike, across a range of geographic and climatic zones. Doing so helped us "de-fang" practitioner perceptions around the risk of pursuing transformational change. When approached from the researcher perspective, a city-practice-centered method can also help to surface other best practices to further study when aggregating results of how cities deal with local conditions and constraints. This takeaway of empowering through play and identifying new practices from scale seems especially important for the pursuit of transformational work with cities: organizations often scolded for innovative practices or policies without well-established histories need social support as well as knowledge and skill building (Lee, 2019).

A common critique of in-person, facilitator-dependent, policy-oriented learning exercises, competitive or collaborative, is the difficulty of using these to reach interested audiences at scale (Vervoot, 2019). Mayer (2009) reference the laboriousness of analog, facilitated games or the difficulty of playing such games with large numbers of people asynchronously. From our perspective, such critiques arise from an emphasis on the "facilitated exercise" as a scalable object.

We argue the focus should instead be on scaling the collaborative process itself, with an emphasis on growing multi-organizational alliances to support distributed action in response to global change challenges (Ostrom, 2010).

Rather than thinking about how to scale facilitation, we would encourage reflection on how to scale the model by which universities, cities, and communities come together to pursue transformative sustainable change in their regions—and then, in this context of transformation, to think about the role of locally-tailored, facilitated capacity-building games. Accordingly, it would then be the models of partnership that need to scale: of universities working in service of the communities in which they are embedded (Crow and Dabars, 2015); of cities seeking to work with frontline communities to implement sustainable transformation for all residents (Park, 2014); of research and action being a single shared process of change management (Caniglia et al., 2020). Questions regarding scale in this context should ask not "if" large audiences can be reached through more activity, but "how?" Asking how, in turn, engenders a creative pursuit of alternative models and a situation in which usable, action-oriented knowledge for sustainability transformation is essential.

Exemplary alternatives can be found in the way other facilitation-intensive deliberative activities have achieved scale in recent years. One example can be seen in trans-national deliberations into to European research and innovation agenda setting (Rosa et al., 2018). Another in the World Wide Views participatory deliberations happen asynchronously, at scale (10,000 people in 97 sessions across 76 countries), as inputs to UN decision making processes (Bedsted et al., 2015) by leveraging local and regional university and informal science education organization partnerships. Questions of "how?" reflect commitment to fidelity of experience, suitability for purpose, appropriateness of players, and ambitiousness of goals—not simply questions of whether more people can be reached. This alternative mode of scaling points to essential action-oriented sustainability research horizons.

CONCLUSION

If urgent sustainability problems are to be comprehensively addressed more is needed from sustainability scientists and practitioners. For sustainability scientists, this means creating more usable knowledge, for city administrators this means taking immediate steps to transform cities toward more sustainable ends. Serious games provide a framework to experiment with different pathways and strategies for sustainability transformation. They can provide a "safe space" to test new ideas, speculate about future consequences of current actions or future impacts of climate change, and consider the range of possible decision options available. AudaCITY is presented as a method for building transformative capacity with city administrations. Players are introduced to transformational sustainability goals, guided through making changes to the structure and function of their cities to achieve those goals, and make explicit connections between those transformations and real actions they can take in their professional roles. By observing how city administrations deliberate and make decisions during serious game play, researchers can develop a more comprehensive understanding of sustainability challenges in context, which can lead to a more informed sustainability science, resulting in more usable knowledge.

The knowledge-action gap in sustainability persists, in part, because knowledge and action continue to be sequenced; first knowledge then action. Sarewitz (2016) wrote in the New Atlantis that scientific knowledge is validated through the creation of artifacts in the real world. He argued compellingly that the validity and merits of a scientific endeavor ought to be based on judgements of its real-world impact and, "Science will be made more reliable and more valuable for society today...by being brought, carefully and appropriately, into a direct, open, and intimate relationship with [societal] influences" (p. 8). A parallel argument can be made about sustainability science specifically: sustainability science advances most rapidly when it is directed toward solving sustainability problems. This is not to say all research must be inspired by use or directed toward solving sustainability problems. Indeed, assessing whether a transdisciplinary approach is appropriate to a particular problem

is an important part of transdisciplinarity in sustainability science (Scholz and Steiner, 2015). Rather, identifying use opportunities of less solution-oriented research—and identifying ways to enhance utility through collaboration or partnership with those who advance such research—is a necessary competence of sustainability science researchers (Wiek et al., 2011). The result may be beneficial for all parties. Less applied researchers may discover additional avenues of data collection and theory building (for example, for deployment of environmental quality or biodiversity monitoring, or studying biogeochemical flows in urban areas, as Long-term Social Ecological Research sites afford in their integration of social, environmental, engineering, and other research communities (Collins et al., 2011). Practitioners may derive valuable information to assist decision making. Sustainability researchers may establish more robust alliances and greater confidence in the soundness of game play or any actions resulting therefrom.

Without deep understanding of how sustainability problems manifest in society, sustainability science is demonstrably worse—less credible, salient, and legitimate (Cash et al., 2003). Contrastingly, sustainability science stands a better chance of being made more reliable and more valuable for society through a direct, open, and dynamic relationship with society. AudaCITY, through a reciprocal knowledge-action relationship, centers urban sustainability challenges as the focus of research; brings research to bear on opening transformative pathways; and seeks to empower participant action for sustainability while further illuminating action-oriented knowledge needs. In doing so, AudaCITY allows sustainability researchers to aide city administrators in pursuing short-term goals while also keeping a long-term perspective in mind. The game also affords researchers the chance to engage long-term research questions associated with building transformative capacity over time, while generating short-enhanced city administrator capacities in the shorter-term. By bringing capacity building and research together in this way, the AudaCITY game offers a valuable method for generating usable, action-oriented sustainability science and improving vital partnerships between cities and universities seeking to serve their local communities as part of a necessary, broad-based response to the challenges posed by global climate change and beyond.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

AUTHOR CONTRIBUTIONS

LK led the research and writing on the article. MB co-led the development of the audacity game and the writing of the article. JN assisted with game development and contributed to writing the article. BK co-led the development of the audacity game and the research. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2022.837578/full#supplementary-material

REFERENCES

Abson, D. J., Fischer, J., Leventon, J., Newig, J., Schomerus, T., Vilsmaier, U., et al. (2017). Leverage points for sustainability transformation. *Ambio* 46, 30–39. doi: 10.1007/s13280-016-0800-y

Alessi, S., and Kopainsky, B. (2015). System dynamics and simulation/gaming: overview. *Simul. Gaming* 46, 3–4. doi: 10.1177/1046878115596390

Bassett, E., and Shandas, V. (2010). Innovation and climate action planning: perspectives from municipal plans. *J. Am. Plann. Assoc.* 76, 435–450. doi: 10.1080/01944363.2010.509703

Bedsted, B., Gram, S., and Jørgensen, M. L. (2015). "WWViews on Biodiversity: new methodological developments and ambitions," in *Governing Biodiversity through Democratic Deliberation*, eds M. Rask and R. Worthington R (Routledge, London), 27–40.

Bishop, I. D. (2011). Landscape planning is not a game: should it be? *Landsc. Urban Plan.* 100, 390–392. doi: 10.1016/j.landurbplan.2011.01.003

Boehnke, R. F., Hoppe, T., Brezet, H., and Blok, K. (2019). Good practices in local climate mitigation action by small and medium-sized cities; exploring meaning, implementation and linkage to actual lowering of carbon emissions in thirteen municipalities in The Netherlands. *J. Clean. Prod.* 207:630–644. doi: 10.1016/j.jclepro.2018.09.264

Brundiers, K. (2016). *Disasters as Opportunities for Change Towards Sustainability (PhD Dissertation)*. Tempe, AZ; Arizona State University.

Bulkeley, H., and Castán Broto, V. (2013). Government by experiment? Global cities and the governing of climate change. *Trans. Inst. Br. Geogr.* 38, 361–375. doi: 10.1111/j.1475-5661.2012.00535.x

Burch, S. (2010). Transforming barriers into enablers of action on climate change: insights from three municipal case studies in British Colombia, Canada. *Glob. Environ. Change* 20, 287–297. doi: 10.1016/j.gloenvcha.2009.11.009

Burch, S., Shaw, A., Dale, A., and Robinson, J. (2014). Triggering transformative change: a development path approach to climate change response in communities. *Clim. Policy* 14, 467–487. doi: 10.1080/14693062.2014.876342

Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martín-López, B., Hondrila, K., et al. (2020). A pluralistic and integrated approach to action-oriented knowledge for sustainability. *Nat. Sustain.* 4, 93–100. doi: 10.1038/s41893-020-00616-z

Cash, D. W., Clark, W. C., Alcock, F., Dickson, N. M., Eckley, N., Guston, D. H., et al. (2003). Knowledge systems for sustainable development. *Proc. Natl. Acad. Sci.* 100, 8086–8091. doi: 10.1073/pnas.1231332100

Caughman, L., and Keeler, L. W. (2020). Real-time evaluation of city – university partnerships for sustainability and resilience. *Sustainability* 12, 8796. doi: 10.3390/su12218796

Chu, E. K. (2016). The governance of climate change adaptation through urban policy experiments. *Env. Pol. Gov.* 26:439–451. doi: 10.1002/eet.1727

Ciplet, D., and Harrison, J. L. (2019). Transition tensions: mapping conflicts in movements for a just and sustainable transition. *Env. Polit.* 29, 435–456. doi: 10.1080/09644016.2019.1595883

Collins, S. L., Carpenter, S. R., Swinton, S. M., Orenstein, D. E., Childers, D. L., Gragson, T. L., et al. (2011). An integrated conceptual framework for long-term social–ecological research. *Front. Ecol. Environ.* 9, 351–357. doi: 10.1890/100068

Crookall, D. (2011). Serious games, debriefing, and simulation/gaming as a discipline. *Simul. Gaming* 40, 193–216.

Crow, M., and Dabars, W. B. (2015). *Designing the New American University*. Baltimore, MD: Johns Hopkins University Press.

Duke, R. D. (2000). A personal perspective on the evolution of gaming. *Simulation and Gaming*. 31, 79–85.

Funtowicz, S., Ravetz, J., and O'Connor, M. (1998). Challenges in the use of science for sustainable development. *Int. J. Sustain. Dev.* 1, 99–107. doi: 10.1504/IJSD.1998.004206

Gibson, R. B. (2006). Sustainability assessment: basic components of a practical approach. *Impact Assess Project Appraisal.* 24, 170–182. doi: 10.3152/147154606781765147

Guston, D. H. (2001). Boundary organizations in environmental policy and science: an introduction. *Sci Technol. Human Values* 26, 399–408. doi: 10.1177/016224390102600401

Hebinck, A., Vervoort, J. M., Hebinck, P., Rutting, L., and Galli, F. (2018). Imagining transformative futures: Participatory foresight for food systems change. *Ecol. Soc*. 23. doi: 10.5751/ES-10054-230216

Heikkinen, M., Ylä-Anttila, T., and Juhola, S. (2019). Incremental, reformistic or transformational: what kind of change do C40 cities advocate to deal with climate change*? J. Environ. Policy Plan.* 21, 90–103. doi: 10.1080/1523908X.2018.1473151

IPCC. (2018). "Summary for policymakers," in *Global Warming of 1.5°C. An IPCC Special Report on the Impacts of Global Warming of 1.5°C Above Pre-Industrial Levels and Related Global Greenhouse Gas Emission Pathways, in the Context of Strengthening the Global Response to the Threat of Climate Change, Sustainable Development, and Efforts to Eradicate Poverty*, eds V. Masson-Delmotte, P. Zhai, H.-O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, and T. Waterfield (In Press).

IPCC. (2022). *Climate Change 2022: Impacts, Adaptation and Vulnerability [Summary for Policymakers]. Working Group II, Intergovernmental Panel on Climate Change*. Available online at: https://report.ipcc.ch/ar6wg2/pdf/IPCC_AR6_WGII_SummaryForPolicymakers.pdf (accessed December 1, 2021).

Ism, C. (2020). How to rule mars. *Presentation at Ted X Munich*. https://www.ted.com/talks/carin_ism_how_to_rule_mars?language=en (accessed September 29, 2022).

John, B., Keeler, L. W., Wiek, A., and Lang, D. J. (2015). How much sustainability substance is in urban visions?—An analysis of visioning projects in urban planning. *Cities.* 48, 86–98. doi: 10.1016/j.cities.2015.06.001

Keeler, L. W., Beaudoin, F., Wiek, A., John, B., Lerner, A. M., Beecroft, R., et al. (2019c). Building actor-centric transformative capacity through city-university partnerships. *Ambio* 48, 529–538. doi: 10.1007/s13280-018-1117-9

Keeler, L. W., Bernstein, M. J., and Selin, C. (2019a). "Intervening through futures for sustainable presents: scenarios, sustainability, and responsible research and innovation," in *Socio-Technical Futures Shaping the Present: Empirical Examples and Analytical Challenges*, eds A. Lösch, A. Grunwald, M. Meister, andI Schulz-Schaeffer. Springer Fachmeiden Wiesbaden GmbH, Wiesbaden, 255–282.

Keeler, L. W., Kay, B., Kelly, G., Logan, G., and Reyes, M. S. (2019b). *Climate Action Plan: City of Tempe 2019, City of Tempe, Tempe, AZ*. Available online at: https://www.tempe.gov/home/showdocument?id=78674 (accessed December 1, 2021).

Krumholz, N., and Wortheim Hexter, K. (2019). "The Future of Equity Planning Practice," in *Advancing Equity Planning Now*, eds N. Krumholz and K. Wortheim Hexter (Cornell University Press), 263–280.

Lang, D. J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., et al. (2012). Transdisciplinary research in sustainability science: practice, principles, and challenges. *Sustain. Sci.* 7, 25–43. doi: 10.1007/s11625-011-0149-x

Lee, T. (2019). Network comparison of socialization, learning and collaboration in the C40 cities climate group. *J. Environ. Policy Plan*. 21, 104–115. doi: 10.1080/1523908X.2018.1433998

Lemos, M. C., and Morehouse, B. J. (2005). The co-production of science and policy in integrated climate assessments. *Glob. Environ. Chang.* 15, 57–68. doi: 10.1016/j.gloenvcha.2004.09.004

Lozano, R. (2014). Creativity and organizational learning as means to foster sustainability. *Sustain. Dev.* 22, 205–216. doi: 10.1002/sd.540

Luederitz, C., Abson, D. J., Audet, R., and Lang, D. J. (2017). Many pathways toward sustainability: not conflict but co-learning between transition narratives. *Sustain. Sci.* 12, 393–407. doi: 10.1007/s11625-016-0414-0

Matson, P., Clark, W., and Andersson, K. (2016). "Linking knowledge with action," in *Pursuing Sustainability: A Guide to the Science and Practice* (Princeton, NJ; Oxford: Princeton University Press).

Mayer, I., Zhou, Q., Keijser, X., and Abspoel, L. (2014). "Gaming the future of the ocean: the marine spatial planning challenge 2050," in *Serious Games Development and Applications: 5th International Conference, SGDA 2014, Berlin, Germany, October 9-10, 2014. Proceedings*, eds M. Ma, M. J. Oliveira, and J. B. Hauge (Springer Cham Heidelberg New York Dordrecht London), 150–162.

Mayer, I. S. (2009). The gaming of policy and the politics of gaming: a review. *Simul. Gaming* 40, 825–862. doi: 10.1177/1046878109346456

Mayer, I. S., Carton, L., de Jong, M., Leijten, M., and Dammers, E. (2004). Gaming the future of an urban network. *Futures* 36, 311–333. doi: 10.1016/S0016-3287(03)00159-9

McNie, E. C. (2007). Reconciling the supply of scientific information with user demands: an analysis of the problem and review of the literature. *Environ. Sci. Policy* 10, 17–38. doi: 10.1016/j.envsci.2006.10.004

Muñoz-Erickson, T. A. (2014). Co-production of knowledge-action systems in urban sustainable governance: the KASA approach. *Environ. Sci. Policy* 37, 182–191. doi: 10.1016/j.envsci.2013.09.014

Nevens, F., Frantzeskaki, N., Gorissen, L., and Loorbach, D. (2013). Urban transition labs: co-creating transformative action for sustainable cities. *J. Clean. Prod.* 50, 111–122. doi: 10.1016/j.jclepro.2012.12.001

Olsson, P., Galaz, V., and Boonstra, W. (2014). Sustainability transformations: a resilience perspective. *Ecol. Soc.* 19. doi: 10.5751/ES-06799-190401

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Glob. Environ. Change* 20, 550–557. doi: 10.1016/j.gloenvcha.2010.07.004

Park, A. (2014). *Equity in Sustainability: An Equity Scan of Local Government Sustainability Programs*, *Urban Sustainability Directors Network*. Available online at: https://www.usdn.org/uploads/cms/documents/usdn_equity_scan_sept_2014_final.pdf (accessed December 1, 2021).

Rathwell, K. J., Armitage, D., and Berkes, F. (2015). Bridging knowledge systems to enhance governance of the environmental commons: a typology of settings. *Int. J. Commons* 9, 851–880. doi: 10.18352/ijc.584

Robinson, J. (2003). Future subjunctive: backcasting as social learning. *Futures* 35, 839–856. doi: 10.1016/S0016-3287(03)00039-9

Rosa, A., Gudowsky, N., and Warnke, P. (2018). But do they deliver? participatory agenda setting on the test bed. *Eur. J. Futures Res.* 6. doi: 10.1186/s40309-018-0143-y

Rumore, D., Schenk, T., and Susskind, L. (2016). Role-play simulations for climate change adaptation education and engagement. *Nat. Clim. Change* 6, 745–750. doi: 10.1038/nclimate3084

Sarewitz, D. (2016). Saving science. *The New Atlantis* 49, 4–40.

Schäpke, N., Bergmann, M., Stelzer, F., and Lang, D. J. (2018). Labs in the real world: advancing transdisciplinary research and sustainability transformation. *Gaia*. 27. doi: 10.14512/gaia.27.S1.4

Scholz, R., and Steiner, G. (2015). The real type and ideal type of transdisciplinary processes: part II—what constraints and obstacles do we meet in practice? *Sustain. Sci*. 10, 653–671. doi: 10.1007/s11625-015-0327-3

Schwarz, J. O., Ram, C., and Rohrbeck, R. (2019). Combining scenario planning and business wargaming to better anticipate future competitive dynamics. *Futures* 105, 133–142. doi: 10.1016/j.futures.2018.10.001

Selin, C. (2011). Negotiating plausibility: intervening in the future of nanotechnology. *Sci. Eng. Ethics* 17, 723–737. doi: 10.1007/s11948-011-9315-x

Stanitsas, M., Kirytopoulos, K., and Vareilles, E. (2019). Facilitating sustainability transition through serious games: A systematic literature review. *J. Clean. Prod.* 208, 924–936. doi: 10.1016/j.jclepro.2018.10.157

Star, S. L. (2010). This is not a boundary object: reflections on the origin of a concept. *Sci. Technol. Human Values* 35, 601–617. doi: 10.1177/0162243910377624

Stummer, M., and Zuchi, D. (2010). Developing roles in change processes—a case study from a public sector organization. *Int. J. Proj. Manag.* 28, 384–394. doi: 10.1016/j.ijproman.2010.01.009

Susskind, L., and Rumore, D. (2013). *Collective Climate Adaptation: Can Games Make a Difference? Solutions 4*. Available online at: http://www.thesolutionsjournal.com/node/2021 (accessed December 1, 2021).

Toth, F. L. (1995). "Policy exercises: the first 10 years.," in *Simulations and Gaming across Disciplines and Cultures: ISAGA at a Watershed*, eds D. Crookal and K. Arai K (Sage, London), 257–264.

Trencher, G., M., Nagao, C., Chen, M., Yarime, K., Ichiki, T., et al. (2017). Implementing sustainability co-creation between universities and society: a typology based understanding. *Sustainability* 9, 594. doi: 10.3390/su9040594

Urban Sustainability Directors Network. (2020a). *About: History*. Available online at: https://www.usdn.org/history.html (accessed December 1, 2021).

Urban Sustainability Directors Network. (2020b). *Practitioner Led Urban Sustainability Workshop. Final Report of a National Science Foundation Sustainable Urban Systems Workshop*. Held 8-10 July 2019, Ann Arbor, Michigan.

Valkering, P., van der Brugge, R., Offermans, A., Haasnoot, M., and Vreugdenhil, H. (2012). A perspective-based simulation game to explore future pathways of a water-society system under climate change. *Simul. Gaming* 44, 366–390. doi: 10.1177/1046878112441693

Van Kerkhoff, L., and Lebel, L. (2006). Linking knowledge and action for sustainable development. *Annu. Rev. Environ. Resour.* 31, 445–477. doi: 10.1146/annurev.energy.31.102405.170850

Vervoot, J. M. (2014). Challenges to scenario-guided adaptive action on food security under climate change. *Glob. Environ. Change* 28, 383–394. doi: 10.1016/j.gloenvcha.2014.03.001

Vervoot, J. M. (2019). New frontiers in futures games: leveraging game sector developments. *Futures* 105, 174–186. doi: 10.1016/j.futures.2018.10.005

Wiek, A., Withycombe, L., and Redman, C. L. (2011). Key competencies in sustainability: a reference framework for academic program development. *Sustain. Sci.* 6, 203–218. doi: 10.1007/s11625-011-0132-6

Withycombe Keeler, L., Beaudoin, F. D., Lerner, A. M., John, B., Beecroft, R., Tamm, K., et al. (2018). Transferring sustainability solutions across contexts through city-university partnerships. *Sustainability*, 10:2966.

Wolfram, M. (2016). Conceptualizing urban transformative capacity: A framework for research and policy. *Cities.* 51, 121–130. doi: 10.1016/j.cities.2015.11.011

Wolfram, M. (2019). Assessing transformative capacity for sustainable urban regeneration: A comparative study of three South Korean cities. *Ambio.* 48, 478–493. doi: 10.1007/s13280-018-1111-2

Wolfram, M., Frantzeskaki, N., and Maschmeyer, S. (2016). Cities, systems and sustainability: Status and perspectives of research on urban transformations. *Curr. Opin. Environ. Sustain*. 22, 18–25. doi: 10.1016/j.cosust.2017.01.014

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