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EDITED BY
Bao-Jie He,
Chongqing University, China

REVIEWED BY
Monica Miles,
University at Buffalo, United States
Nicole Blum,
University College London, United Kingdom

*CORRESPONDENCE
Sara Abercrombie
✉ sara.abercrombie@nau.edu

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Training community engaged climate adaptation leaders using multiple case study analysis: insights from cognitive learning sciences

Sara Abercrombie[1]*, Diana Lynne Stuart[2], Clare Ellsworth Aslan[3], Sara Souther[3] and Brian Craig Petersen[4]

[1]Department of Educational Psychology, Northern Arizona University, Flagstaff, AZ, United States, [2]Department of Sociology, School of Earth and Sustainability, Northern Arizona University, Flagstaff, AZ, United States, [3]School of Earth and Sustainability, Northern Arizona University, Flagstaff, AZ, United States, [4]Department of Geography, Planning and Recreation, Northern Arizona University, Flagstaff, AZ, United States

Training community engaged climate adaptation leaders requires developing learners' thinking skills so they can flexibly approach adaptation planning and problem solving in novel socio-ecological contexts. In this text, we describe how multiple case study analysis helps adult learners in both formal and community education settings develop the thinking skills necessary for adaptation work, including analogical reasoning and knowledge transfer; and we illustrate how to organize multiple case analysis on shared critical competencies aligned to community needs. The article concludes with a discussion of three instructional best practices for employing multiple case analysis in educational settings and a discussion of how this educational approach can guide training programs and funding priorities.

KEYWORDS

climate adaptation, case study analysis, learning transfer, problem-based learning, case-based learning, environmental justice, analogical reasoning

1. Introduction

Responses to climate change-driven challenges typically fall along a spectrum from mitigation (i.e., reducing the intensity of climate effects) to adaptation (i.e., adjusting behaviors and systems to cope with changed conditions) (VijayaVenkataRaman et al., 2012). While climate mitigation is still critically necessary, adaptation efforts are already lagging and there is immense need to create and implement climate adaptation strategies.

While efforts in adaptation planning have been initiated in many places, in most systems such efforts have not yet emerged, remain insufficiently implemented, or fail to holistically consider the social and ecological entities and processes of the system (Moser and Ekstrom, 2010; Measham et al., 2011; Eisenack et al., 2014). Additionally, some existing efforts illustrate a problematic lack of engagement with community members and diverse stakeholders, failing to consider their priorities, concerns, and desired outcomes (Cunningham et al., 2016; Plate et al., 2020). These failures compromise the ability of adaptation efforts to achieve success over the long term, and result in negative outcomes especially for vulnerable populations (Styczynski et al., 2014; Anguelovski et al., 2016).

To serve society fully and retain maximum diversity in both social and ecological realms, adaptation research, planning, and implementation must be inclusive and participatory, led by community needs and prioritizing the involvement of those most marginalized or vulnerable. Climate effects disproportionately impact the most vulnerable, and to effectively respond we need to prioritize *equity* in adaptation: protecting those most burdened by inequality and social injustices (Pelling and Garschagen, 2019). As illustrated by Clark and Miles (2021) it is key to include those voices most often silenced, ignored, or marginalized during adaptation planning and implementation, to address current and legacy environmental injustices perpetuated by social inequities including environmental racism. This is best done through inclusive and participatory means, which are much more likely than top-down prescriptions to effectively help society navigate escalating climate change challenges (Cvitanovic et al., 2019); and researchers suggest that research-based learning programs are uniquely positioned to support adaptation work (Feinstein and Mach, 2020).

As identified by Shi and Moser (2021), current professions across sectors are more reactive than proactive, are not fully considering the complexity of rapidly changing social-ecological systems, lack communication skills, and are not inclusive or prioritizing equity in responses. This "incoherence increases maladaptive investment in climate-blind infrastructure, justice-blind reforms in financial and professional sectors, and greater societal vulnerability to climate impacts" (Shi and Moser, 2021). To ameliorate these problems, and better equip communities to successfully engage in adaptation work, educational interventions specifically designed to address the following critical competencies are imperative:

(1) *Systems thinking*: understand complex social-ecological systems, resilience, and adaptive capacities.
(2) *Convergence research*: conduct convergence research that is transdisciplinary to address societal needs through complex problem solving.
(3) *Transdisciplinary communication*: effectively communicate with stakeholders, policymakers, and the public.
(4) *Climate adaptation planning*: lead proactive and inclusive climate adaptation planning efforts that prioritize equity.

In this paper, we draw from theory and empirical research from cognitive learning sciences to demonstrate how a multiple case study analysis approach can be used to teach critical competencies needed for climate adaptation work across multiple social-ecological contexts. This work aligns with recommendations from the climate education literature to employ curricular and pedagogical resources and approaches to support transformative adaptation work (Feinstein and Mach, 2020; Fioramonti et al., 2021; López-López et al., 2021).

1.1. Multiple case study analysis promotes learning transfer

Learning transfer involves applying knowledge or skills learned in one context to a novel problem or situation, and is considered critical for addressing complex, context-dependent problems such as climate adaptation (Day and Goldstone, 2012). However, research on learning transfer demonstrates that learners often fail to successfully transfer knowledge without clear instructional support, and that novice learners have the greatest difficulty transferring knowledge and skills across contexts (Schwartz and Martin, 2004; Day and Goldstone, 2012). Learning transfer is so difficult because learners struggle to identify which aspects of a problem are contextually bound and which are generalizable, structural problem features; which results in difficulty abstracting and then applying principles from learned examples to new cases (Day and Goldstone, 2012; Goldwater and Schalk, 2016; Borghi et al., 2017).

Evidence-based learning programs for supporting transfer consistently emphasize the importance of interdisciplinary/transdisciplinary collaboration, opportunities to integrate information from multiple sources during decision making, the development of both depth of understanding within a single context and broader application to multiple contexts, and deliberate practice identifying situation-specific problem-solving approaches (Day and Goldstone, 2012; Ferguson et al., 2017; National Science Board, 2020). Multiple-case study analysis is an instructional approach for developing the knowledge transfer skills that support these thinking skills (Gentner et al., 2003). This approach builds on case-study, an inquiry-based learning approach where learning activities center on problem solving within a specific contextualized example (Morgan, 2019).

Case-based instruction is powerful in that it situates learners in an actual problem-solving context where they are engaged in authentic, interdisciplinary scientific inquiry alongside practicing scientists; but it risks bounding the problem and its solutions in the single example which makes transfer difficult. To address this limitation and support analogical learning transfer, we recommend educators employ multiple case study analysis (Gentner et al., 2003). Specifically, this approach requires that learners think in depth about a specific contextual example, and then engage in deliberative comparison between cases, so they learn to recognize similarities and differences, abstract principles, and then resituate those principles across multiple new examples. This process of deliberate, explicit comparison helps learners develop analogical reasoning and deepen their understanding of how to apply knowledge to more effectively solve novel problems (Jonassen and Hernandez-Serrano, 2002; Abercrombie et al., 2019; Morgan, 2019).

1.2. Using justice-focused case studies to promote critical competencies of adaptation planning

In this section, we highlight two case examples, discussed in terms of each of the four critical competencies described above. Since community engagement and equity are overarching goals for our education mission, each of the social-ecological cases is centered on justice focused problem solving. Then, we describe instructive approaches to support the development of climate adaptation leaders.

1.2.1. Case 1: ranching and rangeland biodiversity and sustainable management

Approximately 30% of the US and 25% of all terrestrial habitat globally is classified as rangeland—ecosystems that are regularly grazed by livestock or wildlife (USDA NRCS). Rangelands are large landscapes, spanning diverse topographical, ecological, and social components. Given the geographic extent of rangelands, these systems shape ecosystem services worldwide, including food production, soil formation, carbon sequestration, primary productivity, and water provisioning (Havstad et al., 2007). Humans are integral parts of these rangeland ecosystems, shaping communities for millennia through hunting, burning, and harvesting, and more recently grazing millions of livestock (Hruska et al., 2017). Today, rangeland human communities in the US include several marginalized groups: multi-generational ranchers, subsistence farmers and harvesters, and Indigenous peoples (Sayre et al., 2013).

As US population and economic activity have shifted steadily toward urban centers, rangeland communities often struggle financially, with the result that many families face poverty and isolation or are forced to work multiple jobs in addition to maintaining ranching and other rangeland management activities (Eakin and Conley, 2002; Austin, 2015; Achenbach and Harl, 2018). As a result, combined with climate change and other threats to ranch solvency, many rangeland professionals struggle to maintain their rural way of life, and sales of ranchlands to developers occur each year (Eakin and Conley, 2002). Such rangeland conversion threatens ecosystem services, biodiversity, and cultural legacy across the US West. Immersing students in rangeland history, anthropology, ecology, environmental science, policy, and sustainability studies can develop the four critical competencies as follows:

> Systems thinking: students engaged in multi-disciplinary study of rangelands can grasp past and present social-ecological relationships through an understanding of the history of rangeland management, governance, and overgrazing; familiarization with current legal and financial incentives; and understanding of biodiversity and natural community responses to ongoing environmental change.
> Convergence research: as students work to understand and map sustainable paths forward for ranching communities, they contribute to the preservation of a culturally-important way of life as well as open spaces that are essential for wildlife, aesthetic enjoyment of a broad range of stakeholders and the public, ecosystem services, and future connectivity.
> Transdisciplinary communication: effective adaptation efforts on rangelands facing climate change, habitat degradation, and development pressures require communication with ranchers, agencies (BLM, Forest Service), conservation organizations, recreationists, the public, and policymakers.
> Climate adaptation planning: climate adaptation planning that prioritizes equity would recognize the needs of all players and stakeholders in this system and across these broad landscapes, including the need for ranchers to remain financially solvent, biodiversity to be protected, the public to access open spaces, and agencies to prepare for the future and continue to meet their mandates. Thus, such planning inherently must consider multiple perspectives and values.

1.2.2. Case 2: protecting a social-ecological keystone species

Emory oak (*Querus emoryi* Torr) is a social and ecological keystone species in Arizona forests and savannas. For Western Apache people, Emory oak acorns are an important food source, and in the past were a household staple, "always on the table like salt and pepper" (Coder et al., 2005). Acorn gathering excursions were traditional social events that brought families and, at larger oak stands, clans together, and provided the Western Apache people with both a nutritious food and a product that could be traded for specialty items, like medicinal plants, or sold for income (Coder et al., 2005). While less ubiquitously harvested relative to the past, Emory oak acorns are integrated into all traditional Apache ceremonies. In addition to their value to the Western Apache people, Emory oaks are the dominant species in Madrean oak woodlands and savannas. Oak species appear to stabilize plant communities in woodland and savanna systems possibly preventing conversion to shrubland or desert (McPherson, 1992), provide food and habitat for numerous wildlife species (Hubbard and McPherson, 1997; Long et al., 2017), and likely affect the fate of other species through lesser-studied interaction pathways.

Macro-level shifts in land management and climate have made oak ecosystems increasingly vulnerable to disturbance. Drought, in particular, poses a threat to oaks as projections for the Southwest indicate that these events will increase in frequency and severity. Apache elders, including members of the Yavapai-Apache, San Carlos, White Mountain, and Tonto Apache Nations, have expressed concern over how changing conditions in the region will impact traditional acorn harvest and the harvest of other culturally-important plant species. In response, a unique collaboration between western Apache Nations, the US Forest Service, which manages 70% of Emory oak habitat in Arizona, industry, and researchers at Northern Arizona University emerged to ensure the long-term persistence of Madrean oak woodlands and savannas and the cultural practices linked to the Emory oak, under the direction of Apache Elders. As collaborative restoration and adaptation efforts are increasing, it is critical to ensure that Emory oak as a social-ecological keystone species is prioritized in these efforts and that tribes drive this process, holding leadership roles in identifying areas for preservation, planning, and management.

> Systems thinking: a holistic model of this coupled socio-ecological system, including identification of feedback mechanisms and tipping points, is necessary to understand key relationships. Students can help to examine social science data from interviews with tribal members to make linkages with ecological data. Working together to build a systems map and identifying key drivers of change is essential for planning restoration, adaptation, and preservation efforts.
> Convergence research: this research was requested by tribal members and is being guided by tribal priorities. Students involved see first-hand how social justice focused work occurs. Working with the US Forest Service and other organizations

provides experience and skills for working with diverse actors across jurisdictions and introduces students to new ways that research can be used beyond the university.

Transdisciplinary communication: key to this project is effective communication between all involved parties. Work prioritizing social justice requires active listening and two-way communication. Beyond meetings and presentation, more active forms of communication and planning can occur that bring diverse actors together to map out key areas for restoration and more actively design participatory strategies.

Climate adaptation planning: these efforts prioritize tribal community and social-ecological sustainability and thus will be directed and led by tribal elders and leaders. A clear leadership network exists to guide decision-making in ways that ensure these priorities are upheld.

2. Discussion

Consideration of just two cases in comparison demonstrates both thematic commonalities across the four critical competencies as well as variation in the goals, approaches, and stakeholders involved in adaptation work. While multiple case comparison promises to teach individuals how to consider such complexities applied to varied and novel contexts, how might this method of instruction be best employed? In this section, we describe three application strategies to advance climate adaptation training in varied educational settings.

2.1. Organize case analyses around broader conceptual themes

Decades of research on learning transfer suggests that when learners organize content around a generalized concept (expansive framing), they are better able to transfer their knowledge to new settings (Gick and Holyoak, 1983; Engle et al., 2012). In case study, this means that the learners are directed to organize their understanding both in terms of the details of the case and a broader conceptual structure, resulting in knowledge organized both concretely and abstractly (Day and Goldstone, 2012). In our example, we present two distinct climate adaptation cases around four critical competencies aligned to adaptation priorities. During instruction, educators may guide learners to identify examples and nonexamples of each critical competency with each individual case, to map the concrete details of the cases to the conceptual themes. This would enrich both the learners' understanding of each individual case and the critical competencies, which lays the initial groundwork for analogical transfer to new contexts.

2.2. Engage learners in explicit and iterative case comparison

Requiring learners to engage in explicit case comparison supports learning transfer by drawing out similarities and differences between the cases, including differences across time, ecosystems, social contexts, power dynamics, and other key features (Gentner et al., 2003; Kurtz et al., 2013). Educators should not assume that learners will automatically and independently recognize shared themes across different problems; indeed, research shows that novice learners often fixate on surface features and fail to see conceptual features across problems and cases (Chi and VanLehn, 2012). It is therefore necessary to provide multiple opportunities for explicit comparison across cases and learning sessions, including revisiting prior conceptualizations to further support concept development.

2.3. Avoid overzealous transfer to support future learning

Even when learners develop robust conceptual understanding about a set of problems, they still risk bounding future problems with solutions from the past, resulting in overzealous transfer (Schwartz et al., 2012). In terms of climate adaptation, this tendency risks algorithmically applying past solutions to new settings, because these approaches have been successful before. To avoid this tendency, as learners engage with new cases, they should be required to seek feedback from their instructors, peers, and community stakeholders about the adequacy of how they frame the problems presented in the case, as well as discuss what contextual features are distinct from other cases. Explicitly teaching learners that such interdisciplinary and transdisciplinary dialogue is necessary for successfully navigating novel cases will support their learning and prepare them to better engage in climate adaptation leadership in the future.

2.4. Moving forward: supporting learning across case studies

To support the development of future climate adaptation leaders, students should have exposure to multiple case studies so they become adept at conceptualizing how to address problems in novel cases they will encounter later in their education and careers. While being deeply involved in multiple case studies is beyond the scope of most theses or dissertations, even when students are focused on a singular case study, learning across cases can be facilitated through planning, deliberate learning interventions, and collaborative cross-case study processing and discussion.

For example, in the cases described above, students involved in the first case study will have an understanding of the values and priorities of ranchers and those involved in the second case study will have an understanding of the goals and priorities of Native American tribal elders and community members. In each case, transdisciplinary communication and planning will involve different socio-ecological context, stakeholders, and decision-makers; yet, the key competency areas apply to both case studies and students can identify shared themes across cases. This helps to facilitate a broader understanding of adaptation work as well as an

understanding of the importance of specific social and ecological context in each case study.

Supporting multiple case study analysis requires coordinated research among principal investigators working in diverse social-ecological systems. Ideally, this would involve more than two different case studies (e.g., three to five cases); and coordination among investigators to focus on the same key competencies. In other words, social-ecological research to train students to be leaders in adaptation research and planning requires forethought and collaboration—both essential elements for adaptation work generally.

University faculty members and other principal investigators in social-ecological research clearly face time and resource constraints that make such forethought and collaboration difficult. However, we argue that to address the concerns articulated by Pelling and Garschagen (2019) and Shi and Moser (2021), and develop an adaption-ready workforce, this type of training is necessary and needs to be supported. Therefore, we recommend universities, funding organizations, and other institutions develop specific programs and outlets for this essential cross-case adaptation training. For example, at a specific university, a "Center for Adaptation" can be established that brings together researchers and students working on diverse social-ecological systems facing adaptation challenges. Organizations, such as the National Science Foundation, already offer funding for coupled-systems research and transdisciplinary graduate student training. However, more funding specifically to train students in adaptation science and planning is critical to build the capacity to address current and future challenges. Adaptation efforts continue to be reactionary and inadequate (Shi and Moser, 2021), and student training is required that not only builds skills applicable to diverse social-ecological systems but that also prioritizes giving those most affected by climate change a leading role in adaptation planning (Cunningham et al., 2016; Plate et al., 2020).

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

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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