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Core Competencies for Training Conservation Paleobiology Students in a Wicked World

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Despite the promise conservation paleobiology holds for using geohistorical data and insights to solve conservation problems, training in the field typically does not equip students to be competent environmental problem solvers. The intention of this perspective piece is to start a conversation about how we might train conservation paleobiology students better, focusing on the competencies needed to promote deep engagement with "wicked" conservation problems that are difficult to solve. Ongoing conversations regarding design of academic programs in sustainability, a field allied with conservation science, can inform our discussion. The sustainability literature has defined an interrelated set of "core competencies" that go beyond general academic competencies to enable real-world sustainability problem solving: systems thinking, temporal thinking, normative thinking, strategic thinking, and interpersonal competence. Conservation paleobiology is usually taught within geology programs, where students are exposed to systems thinking and temporal thinking. However, the remaining competencies typically are absent or insufficiently developed. To infuse these competencies into conservation paleobiology curricula, we recommend: (1) enhancing connections with sustainability programs and encouraging a more cross-disciplinary approach to training; (2) developing a "menu" of concepts and methodologies for each competence from which to choose; and (3) recognizing that different skills are appropriate at different levels of education and experience. The proposed competency-based framework serves as a shared reference that can be used to develop pedagogies to better prepare conservation paleobiology students to navigate the wicked conservation challenges of our time.

Keywords: cross-disciplinarity, key competencies, solution-oriented science, sustainability, training, wicked problems

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INTRODUCTION

Many, if not most, environmental problems are "wicked problems" (Rittel and Webber, 1973). These problems are deeply embedded in disagreements among stakeholders, who often have opposing views on a problem and its causes; wicked problems lack clear solutions, and attempts to solve them can lead to unexpected consequences. As a solutions-oriented discipline, conservation paleobiology (CPB) aims to address the wicked problem of biodiversity loss (Game et al., 2014) by generating knowledge from the geohistorical record (fossils, sediments, and other natural archives) to inform and shape the policies and practices that protect biodiversity (Dietl et al., 2015).

This goal is laudable; however, in a fractal-like way, it also creates a wicked problem of its own for conservation paleobiologists. We have argued (Kelley et al., 2018, 2019) that the traditional disciplinary academic experience of most of today's conservation paleobiologists constrains our ability to prepare students to solve conservation problems. Our conventional background in the science of paleontology has not prepared us to train students for conservation careers other than research-based academic appointments. Yet, the wicked nature of many conservation problems demands an evolution in the way we train students.

Therefore, the intention of this perspective piece is to start a conversation about the competencies needed to prepare CPB students to be effective environmental problem solvers. Our hope is that by adopting core competencies for CPB programs, we will be able to better train the next generation of students, enabling them to tackle the wicked conservation challenges of today and tomorrow.

INSIGHT FROM SUSTAINABILITY SCIENCE

Previously (Kelley et al., 2018), we have looked to conservation biology, a sister field to CPB within the conservation sciences (Dietl, 2016), for insight into how best to train students to function effectively in the conservation world. Indeed, the conservation biology literature includes much discussion about approaches to training, including how to balance depth vs. breadth of curriculum (Jacobson and Robinson, 1990; Muir and Schwartz, 2009), the need for cross-disciplinary training (Newing, 2010; Turner et al., 2016), emphasis on policy (Clark, 2001), and practical experiences such as internships (Moslemi et al., 2009). Various skills have been identified, from technical to interpersonal "soft skills" (Blickley et al., 2012; Lucas et al., 2017; Englefield et al., 2019). However, a coherent overarching framework to guide academic program development is lacking.

Sustainability is a field allied with conservation sciences (Kareiva and Marvier, 2012), and geoscientists are beginning to advocate greater integration of the geosciences and sustainability science (Bennington et al., 2015; Wessel and Greenberg, 2016; Stewart and Gill, 2017; Fildani and Hessler, 2021). Like CPB, sustainability is an emerging academic field that confronts wicked problems (e.g., climate change, water scarcity, extreme poverty, COVID-19 pandemic), but it has expanded much more rapidly; as of 2016 there were nearly 2,400 programs focused on sustainability in the United States alone (Engle et al., 2017). The rapid proliferation of academic programs and the interest in sustainability beyond academia have spurred efforts (e.g., De Haan, 2006; Barth et al., 2007) to develop a framework of competencies to guide pedagogical approaches. These endeavors are consistent with an expanding global interest in competency-based learning in general (e.g., Voorhees, 2001), with competency considered to be a combination of knowledge, skills, abilities, attitudes, and/or behaviors necessary for performing specific tasks (U. S. Department of Education, National Center for Education Statistics, 2002; Davis et al., 2004).

Specifically with regards to sustainability, Wiek et al. (2011a, p. 204) have defined competencies as "complexes of knowledge, skills, and attitudes that enable successful task performance and problem solving with respect to real-world sustainability problems, challenges, and opportunities." Wiek et al. (2011a, p. 204) argued that, rather than a "laundry list" of disconnected competencies, sustainability science needed "conceptually embedded sets of interlinked competencies," which they termed "key competencies" (also referred to as "core competencies" or "meta-competencies"; see Engle et al., 2017). A consensus is emerging in sustainability science regarding these core competencies that can guide academic program and course design to prepare students to act as problem solvers (Wiek et al., 2011a; Engle et al., 2017; Evans, 2019; Brundiers et al., 2021). These competencies go beyond general academic competencies, such as knowledge of the discipline, communication skills, and the ability to think critically (which are important in any field), and are focused on competencies needed to enable real-world sustainability problem solving. We suggest here that similar competencies are appropriate for training students in CPB and, more broadly, the conservation sciences.

CORE COMPETENCIES

To identify core competencies, several authors (Wiek et al., 2011a; Engle et al., 2017; Lozano et al., 2017; Evans, 2019) reviewed the sustainability literature for higher education; Engle et al. (2017) and Evans (2019) also reviewed the workforce development/professional literature. Although terminology varied slightly among authors, five core competencies were identified in sustainability science: systems thinking, temporal thinking, normative thinking, strategic thinking, and interpersonal competence (Wiek et al., 2011a; Engle et al., 2017). Wiek et al. (2016) subsequently acknowledged a sixth meta-competency, integrated problem-solving, that involves integrating and using the other five competences for solving sustainability problems, which Evans (2019) referred to as transdisciplinary competence. More complex schemes have been proposed (Rieckmann, 2012; Lozano et al., 2017), but the additional proposed competencies can be subsumed within the competencies of Wiek et al. (2011a, 2016). We base our discussion on the framework of Wiek et al. (2011a) because it is the most widely cited and employed by sustainability programs worldwide (Brundiers et al., 2021).

Systems Thinking Competence

Engle et al. (2017) noted that nearly all the sustainability literature they reviewed mentioned the importance of competence in systems thinking (=resilience thinking; Walker and Salt, 2006). Solving real-world sustainability problems requires understanding and analyzing social-ecological systems,[1] including their structure, components, and dynamics (Wiek et al., 2011a). Such analysis may occur at a range of geographic scales (local, regional, and global) and incorporate a variety of domains (ecological, environmental, cultural, economic, technological, political, etc.). Competence in systems thinking provides a lens that enables students to better perceive and understand the complex web of social and ecological relations and identify the likely drivers of problems (Betley et al., 2021). We can then think about creative ways to address these problems (e.g., locating interventions; Fischer and Riechers, 2018).

As with sustainability issues, most conservation challenges (e.g., biodiversity loss) are embedded in complex, social-ecological systems. Despite widespread recognition of this complexity, systems thinking has not been widely incorporated into conservation practice (e.g., Stirling et al., 2010; Knight et al., 2019; Sala and Torchio, 2019). Davila et al. (2021) argued convincingly, however, that systems thinking can support more integrative biodiversity interventions. Systems thinking is not envisioned as a panacea for all the world's conservation problems. It does, however, provide a foundation for "transformative conservation" in practice (Fougères et al., 2020). Likewise, CPB students will benefit from competence in systems thinking, which is fostered to varying degrees within geoscience departments where teaching Earth Systems Science is pervasive (Orion and Libarkin, 2014; see also Stewart and Gill, 2017).

Temporal Thinking Competence

Reviews of the sustainability education literature identified a competency related to the concept of time, termed "anticipatory competence" by Wiek et al. (2011a) to refer to the ability to anticipate and evaluate "pictures" of the future ("foresighted thinking" of De Haan (2006)). Engle et al. (2017) preferred the term "temporal thinking" (as do we) to acknowledge the role that knowledge of past states of systems must play in anticipating and evaluating future scenarios (see Dietl, 2019).

Temporal thinking includes the "ability to extract and apply lessons from the past" (Engle et al., 2017, p. 293), which is integral to CPB (Dietl et al., 2015). Because CPB is typically taught in geology programs, temporal thinking—the practice of timefulness (*sensu* Bjornerud, 2018)—is already ingrained in CPB training. Kastens et al. (2009, p. 265) identified thinking about time, in its full richness and depth, as a hallmark of the geoscience perspective; geoscientists "take a long view of time.... They can envision Earth in states drastically different from the planet they have personally experienced." Consequently, this long-term perspective should be a critical component of environmentally responsible decision making (Kastens et al., 2009).

Despite acknowledgment that sustainability education requires competence in temporal thinking, the long-term perspective of the geosciences has largely been left out of sustainability programs (Fildani and Hessler, 2021). A geologic habit of mind is not the norm. Indeed, conservation biologists recognize the importance of long-term data but tend to define "long-term" as decades (Smith et al., 2018). Nevertheless, long-term durable solutions to problems, rather than temporary mitigation strategies, require understanding of how Earth's systems operate through time (Fildani and Hessler, 2021). Conservation paleobiology must be a part of these efforts.

Normative Competence

Wiek et al. (2011a, p. 209) defined normative competence as "ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets." Brundiers et al. (2021, p. 24) identified this competency as the lead competency that "provides the normative orientation for all others." Likewise, normative values in CPB are inescapable because conservation problems are often tangled in a web of non-epistemic value judgments (Baumgaertner and Holthuijzen, 2017; Bennett et al., 2017; Buschke et al., 2019). Yet, consideration of ethical issues such as justice and equity in environmental solutions is not a traditional part of geoscience education, which leaves many conservation paleobiologists ill-prepared for the ethical challenges that arise during conservation research. We argue that a normative, or values, competence should be a part of CPB (Dietl, 2016). See also Stewart and Gill (2017).

Lack of understanding of how our values and beliefs shape CPB research limits our ability to contribute to conservation solutions in situations where social inequity and conflicts in values occur (Boyce et al., 2021). We need to understand not only the value system that underpins and influences our work (which, as with conservation biology, is deeply rooted in Western normative values of nature and conservation; Yanco et al., 2019; Boyce et al., 2021), but also how our personal values and beliefs shape our research and interpretations. Developing such an attitude of reflexivity (Beck et al., 2021; Boyce et al., 2021) will enable us to become better attuned to potential value-based conflicts and their consequences. Without acknowledging that conservation is a normative endeavor, and recognizing and learning from different ways of knowing and valuing, we will be unable to identify longer lasting, fairer, more just and more equitable solutions to conservation problems.

Strategic Thinking Competence

Strategic competence (Wiek et al., 2011a) is the ability to collaboratively design and implement appropriate interventions, solutions, and governance strategies that address sustainability problems. In other words, strategic competence is the ability to develop a plan to achieve a particular vision. Wiek et al. (2011b, p. 7) aptly described strategic competence as "where the rubber meets the road," i.e., where the knowledge and skills that make up the other competencies are translated into action. In addition, Brundiers et al. (2021) recently suggested including the ability to

[1] Sustainability researchers are beginning to draw on relational thinking as a way of overcoming a largely implicit assumption that is often made in thinking about social-ecological systems—that is, the separation of the social from the ecological. Hertz et al. (2020) suggested that this bias (rooted in substance ontologies that are common in science today) impedes our ability to understand social-ecological systems as truly co-constituted and intertwined. Relational thinking (grounded in process ontology) is seen as way forward (e.g., Cooke et al., 2016). [See West et al. (2020) for a more detailed discussion of this "relational turn" in sustainability science.]

engage in and lead radical change to break the *status quo* as a key element of strategic competence. Although Engle et al. (2017) did not use the term strategic competence, interviews of sustainability experts and practitioners revealed an emphasis on creativity and imagination, producing an "ability to envision, develop and apply innovative and strategic solutions and frameworks in order to adapt to changing and challenging situations" (p. 298; see also Evans, 2019). Such strategic competence currently is not an outcome of CPB training, but this competence will facilitate translating paleontological knowledge into conservation action.

Interpersonal Competence

Engle et al. (2017) noted that all the reviewed literature on sustainability education, as well as conversations with experts and practitioners, placed a premium on interpersonal literacy (=interpersonal competence of Wiek et al. (2011a)). This competence reflects the ability to understand and empathize with persons of diverse viewpoints; to communicate, negotiate, and collaborate with scientists and stakeholders across disciplines, cultures, social groups, and organizations; and to motivate and enable problem solving. Interpersonal competence cross cuts all other competencies in that it is required to enable use of any of the other competencies (Wiek et al., 2011a).

The need for such soft skills has been recognized previously in the conservation sciences (Blickley et al., 2012; Lucas et al., 2017). Requisite skills include communication (e.g., Elliott et al., 2018; Wallen et al., 2019), including through social marketing, in which few practitioners are trained (Robinson et al., 2019); however, graduate programs provide little training in science communication and outreach (Hunnell et al., 2020; Triezenberg et al., 2020). Leadership skills are also crucial (Elliott et al., 2018; Englefield et al., 2019) in achieving conservation goals, but despite their importance in building trust among stakeholders, such competencies are missing from most conservation training (Englefield et al., 2019). Teamwork and collaboration (Chapman et al., 2015; Elliott et al., 2018; Turgeon et al., 2018) with researchers across disciplines (Wallen et al., 2019) and with stakeholders (Turgeon et al., 2018) are also vital.

We have previously (Kelley et al., 2018) advocated for CPB training that develops interpersonal skills through formal course work, research experiences, internships with government agencies and NGOs, and less formal activities. If conservation paleobiologists are to collaborate successfully with diverse groups of conservation practitioners and other stakeholders, we must ensure that interpersonal competencies are met.

RECOMMENDATIONS

To prepare CPB students to tackle wicked conservation problems, we recommend structuring CPB training programs around the five competencies identified for programs in sustainability. Temporal thinking is already integral to CPB, and the geoscience context of typical CPB training also exposes students to systems thinking, although students would benefit from increased emphasis on the human dimension of social-ecological systems. Previously, we recommended approaches to fostering interpersonal competence, e.g., through real-world experiences such as internships (Kelley et al., 2018) taken in addition to or perhaps in place of traditional geology "field camps" depending on the goals of the student (or program). Normative and strategic competencies may be more difficult to integrate into CPB education, however.

We recognize that we can't do everything; CPB students will still need fundamental courses such as historical geology, paleoecology, stratigraphy, and field methods. However, we may be able to inject missing competencies into CPB curricula by forging connections with sustainability programs, which are much further developed and more common than programs in CPB. Such connections (e.g., cross-listing courses, team teaching or co-advising across disciplines, offering joint certificate programs) are consistent with the call for greater integration of geosciences and sustainability science. They also correspond to the widely held view that training in conservation must be cross-disciplinary (Jacobson, 1990). CPB students would benefit from coursework not only in the natural sciences (e.g., conservation biology) but also from social science electives (e.g., economics, political science, sociology, philosophy, environmental ethics; see Kelley et al., 2018).

We also find merit in an approach advocated by the Community of Practice for Core Competencies of the National Council for Science and the Environment, now the Global Council for Science and the Environment[2]. Each competence can be represented by a "menu" of concepts and methodologies from which students (or programs) can choose, because the competencies are collective. In other words, individuals are not expected to develop expertise in every concept and method of each competency. Instead, problem solving can draw on the distributed expertise of teams (Wiek et al., 2011a).

In addition, following Wiek et al. (2016), we recognize that different skills are appropriate at different levels of education (undergraduate, master's, or doctoral programs) and experience. For example, a novice in interpersonal competence should be able to identify the stakeholders relevant to a project, whereas individuals at more advanced levels would be involved in stakeholder engagement, and ultimately in negotiation and resolving conflict (Wiek et al., 2016). Ongoing training allows skills to be added at any point, as the process of competence acquisition is iterative (Wiek et al., 2016).

INVITATION TO A COMMUNITY DIALOG

Our intention is not to advocate that these competencies be "set in stone" for CPB, and it would be premature to recommend how to incorporate such competencies into a CPB curriculum. Indeed, even in the well-developed sustainability literature, conversation continues about relationships among competencies and whether separate competencies are needed for intrapersonal (= self-reflexive) and implementation skills (Brundiers et al., 2021). Instead, our goal is to initiate a respectful and inclusive dialog within the CPB community about the need for competencies, the utility of this framework, and any modifications that would help us better prepare our students to navigate the wicked

[2] https://gcseglobal.org/

conservation problems of today and those of the future. Such a conversation ultimately will lead to creating learning objectives and identifying the pedagogical approaches that will best advance these objectives (see, e.g., Lozano et al., 2017).

AUTHOR CONTRIBUTIONS

GD suggested the idea for this topic. PK and GD contributed equally to researching, writing, and editing of the manuscript. Both authors approved the submitted version.

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