DISSERTATION

LEARNING TO REASON, LEARNING TO LEAD: FROM WORLDVIEWS TO PROFESSIONAL IDENTITIES IN ECOLOGY EDUCATION

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ABSTRACT

LEARNING TO REASON, LEARNING TO LEAD: FROM WORLDVIEWS TO PROFESSIONAL IDENTITIES IN ECOLOGY EDUCATION

Rapid environmental change has made clear that solving ecological problems depends as much on how people make decisions based on what they know. Scientists and natural resource managers must navigate issues that are ecological and technical as well as social, ethical, and political. Because universities prepare many of the people who will face these challenges, ecology and natural resource management (NRM) programs play a central role in shaping how future professionals and decision makers (e.g., voters, taxpayers) learn to interpret information, weigh evidence, and act within complex decision systems. This dissertation examines how students develop and apply decision-making competencies across educational stages (i.e., undergraduate and graduate). Guided by the Values-Rules-Knowledge framework, I examine how students draw on different forms of understanding, norms, and authority when responding to social-ecological problems. In Chapter 2, I explore how undergraduate ecology students reason about socioscientific issues such as species introduction and disease spread, highlighting how their worldviews influence what evidence they consider to be credible or important. Chapter 3 focuses on students' "socioscientific capital," or the knowledge, experiences, and values they use when explaining or justifying environmental decisions. Finally, Chapter 4 follows graduate students in a community-based NRM course as they consider how their worldviews influence their perceptions of their professional role. These studies illustrate the importance of educational spaces and how they shape how students are becoming ecological thinkers and practitioners.

Collectively, this dissertation advances understanding of the role of worldviews in decision-making and offers insight into how instruction can promote the development of ecologically literate professionals.

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The number of giants whose shoulders I have stood on throughout my academic journey seems infinitesimal. However, there are a few folks who provided extra guidance along the way. To my family, who gave me the ladder without knowing where it would take me – but who saw that it got me closer to the stars. You gave me the courage to reach for shoulders I couldn't yet see and the faith to believe they would hold me. To my friends, who stood beside me when the view from those shoulders felt unsteady. You reminded me to look around, not just ahead, and to notice the beauty of where I was and the people holding me up. You made even the tallest giants feel less intimidating and the heights less lonely. And to my advisor and committee, whose own shoulders became part of the towering lineage I joined. You offered both stability and perspective, teaching me how to balance gratitude with independence, humility with confidence. You showed me that standing on the shoulders of giants is not only about seeing farther, but also about learning how to lift others in turn.

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CHAPTER 1

INTRODUCTION

Environmental socioscientific issues (SSIs), such as urban wildlife management and climate adaptation, sit at the intersection of science and society (Zeidler & Nichols, 2009). In other words, people use scientific knowledge to make decisions about issues that are socially important. In these contexts, students do not arrive as blank slates; they bring structured meaning systems formed through culture, experience, and schooling that shape how new information is interpreted and used in argumentation (Bossér & Lindahl, 2019). SSI-oriented science education aims to support scientific literacy, reasoning, and identity by engaging students in evidence-informed decision making about issues that matter beyond the classroom (Högström et al., 2024; Ke et al., 2021; Kolstø, 2001). Because SSI tasks involve trade-offs and moral considerations, they make visible the resources students draw upon when they reason. Recent work conceptualizes these resources as socioscientific capital (SSC), or the internal (e.g., experiences, values, skills, disciplinary knowledge), external (e.g., family, peers, media, community), and meta-level (e.g., dominant societal narratives) resources available for sensemaking (Klaver et al., 2023). We extend this lens by arguing that worldview, a student's evolving system of meaning about human–nature relations, morality, and knowledge (Hedlund-de Witt, 2014), functions as a filter that selects and weights SSC during reasoning. This perspective helps explain familiar puzzles in ecology classrooms: why students with similar content knowledge justify opposing positions and may use different evidence to support their positions, why the same student reasons differently across tasks, and how classroom discourse can reproduce or contest broader narratives (Rundgren et al., 2016).

Despite substantial research on SSIs, argumentation, and values/worldviews in the context of undergraduate education (which we outline below), the field lacks an integrative synthesis that organizes evidence around the mechanisms linking culture, person, and practice in environmental SSIs. This review addresses that gap. In this dissertation, we a) define core constructs and distinctions; b) synthesize findings along the pathways of a layered model (Meta → Worldview → SSC → Reasoning, with feedback); and c) highlight concrete ideas that future research could investigate within undergraduate ecology classrooms.

Environmental SSIs support ecological literacy

Undergraduate ecology classrooms are important sites for preparing students to engage with pressing environmental challenges. One way to accomplish this is through SSIs. Environmental SSIs, in particular, ask students to apply ecological concepts to contested issues while also grappling with values and uncertainty. Because these issues reflect the complexity of the social-ecological systems students encounter beyond the classroom, they offer a promising pathway for advancing ecological literacy. To situate this claim, it is necessary to first clarify what is meant by "literacy" in this context.

What do we mean by (scientific, environmental, and ecological) literacy?

The idea of "literacy" has evolved well beyond reading and writing to describe the knowledge and skills people need to participate meaningfully in different areas of life (Roth, 1992). In science education, "scientific literacy" is often defined as the ability to use scientific knowledge and practices to make informed decisions about real-world problems (Bingle & Gaskell, 1994). Roberts and Bybee (2007; 2014) explain this through two "visions" of literacy: Vision I emphasizes science content and methods as defined by scientists, while Vision II emphasizes using science to address issues that are socially and personally relevant. Both are

important, but Vision II is especially critical for preparing students to reason about SSIs, where evidence and values may support or conflict with each other. While scientific literacy is the broadest frame within the sciences, specialized versions have emerged to better fit the goals, audiences, and disciplinary norms of specific fields.

Within environmental education, the concept of "environmental literacy" has been developed and refined since the 1970s to capture what it means to understand and act on environmental issues (Roth, 1992). Most frameworks describe four main components (see McBride et al., 2013 for a review): 1) knowledge of ecological systems, environmental issues, and socio-political structures; 2) competencies to analyze issues, evaluate evidence, and justify solutions; 3) affective dispositions such as interest, motivation, and worldview; and 4) environmentally responsible behaviors, which are considered the ultimate demonstration of literacy in practice. In short, environmental literacy includes one's knowledge and how they think, feel, and act towards the environment. Historically, environmental education programs developed apart from the ecological sciences, emphasizing interdisciplinarity and civic engagement (Rana, 2013). More recently, however, the two areas have begun to overlap, while still retaining distinct goals for a literate community of practice.

A related but more discipline-specific construct is "ecological literacy." This idea originated within the field of ecology itself (McBride et al., 2013). Ecological literacy focuses on understanding ecological principles and systems-thinking, while still recognizing the importance of applying that knowledge in decision-making contexts (Balgopal & Wallace, 2009). Early framings, such as those by Risser (1986) and Orr (1992), argued for curricula that prepare students to see the connections within ecosystems and between ecological and human systems (also termed coupled human-natural systems (J. Liu et al., 2007) and social-ecological systems

(Berkes & Folke, 2000)). More recent efforts, including the Ecological Society of America's Four-Dimensional Ecology Education (4DEE) Framework, offer a structured way to teach and assess ecological literacy (Klemow et al., 2019). This framework was shaped by prior national reforms in science education, including AAASs' *Vision and Change in Undergraduate Biology Education* and the K-12 *Next Generation Science Standards*, both of which were designed to promote scientific literacy. Like environmental literacy frameworks, the 4DEE Framework identifies four dimensions that broadly encompass ecological knowledge, human-environment relationships, making sense of complex systems, and applying ecological practices. In this review, we focus specifically on ecological literacy because it most closely aligns with the goals and context of undergraduate ecology classrooms. Nevertheless, students need opportunities to apply ecological knowledge in situations where ecological and social systems are connected. This is where environmental SSIs play a critical role.

Environmental socioscientific issues (SSIs)

Socioscientific issues, in general, are complex, real-world problems that are both scientific and societally relevant (Zeidler & Nichols, 2009). They are intentionally broad and not tied to any specific discipline. For example, in health education, SSIs might include debates over vaccination policies or the use of genetic testing (Calavia et al., 2024; Herman et al., 2022; Sadler & Zeidler, 2005). In physics, energy production and nuclear power are common SSI contexts (Jho et al., 2014; Sakschewski et al., 2014). Across these fields, SSIs provide opportunities for students to engage in science in ways that are socially relevant and personally meaningful.

Environmental SSIs form a specific subset of these issues, focusing on societal challenges that link environmental systems with human decisions and values (Herman et al.,

2017). These include topics such as climate change, pollution, water scarcity, biodiversity loss, or the management of natural resources[1]. Because they connect ecological and social systems, environmental SSIs provide a particularly strong context for supporting ecological literacy. Like the case of all SSIs, environmental SSIs require that students draw on and evaluate disciplinary knowledge, among other forms of knowledge, to make decisions. For instance, real-world issues, like wolf reintroduction, require students to apply ecological concepts like trophic interactions or population dynamics while also considering community values and traditions . Thus, environmental SSIs create opportunities to practice the core components of ecological literacy frameworks, including knowledge, competencies, and seeing the connection between human and social systems. In reasoning through environmental SSIs, students can see how ecological principles extend beyond the classroom and into the societal challenges they may face as citizens and professionals.

Research on environmental SSIs has grown in recent decades and shows clear benefits for student learning. In a recent review of 61 studies published over the last decade, Kumar and colleagues (2024) found that in more than half of the articles, students developed both action-oriented skills, like decision-making, and non-action-oriented skills, like argumentation. While much of this work has been focused on global issues like climate change, some studies highlight the value of incorporating local environmental SSIs in classrooms (Capkinoglu et al., 2020; Kong, 2021; Lee & Grace, 2010; Purwasih et al., 2025). Local issues can be especially powerful because they connect directly to students' lived experiences and community practices, while also making the role of values and beliefs in decision making more visible. For instance, communities

[1] Although we distinguish environmental literacy from ecological literacy, we do not draw a hard line between "environmental" and "ecological" SSIs. These issues are simultaneously environmental and ecological in nature, and thus we treat environmental SSIs as fully applicable to the context of ecology classrooms.

often struggle to adopt sustainable practices when proposed solutions conflict with traditions, livelihoods, or daily needs. When students analyze local SSIs, they reflect on the beliefs and practices that shape decisions in their own families and communities.

Although argumentation and decision making are well-documented outcomes of SSI instruction, far less is known about how students' personal values, cultural norms, and worldviews influence their reasoning. Fang, Hsu, and Lin (2019) argue that this dimension has received too little attention, and Rudsberg and Öhman (2015) similarly stress the need for approaches that help students question their own assumptions and perspectives. Their work suggests that environmental SSIs provide a bridge between literacy and the personal meaning-making frameworks that students bring with them to the classroom. Students arrive with preconceived ideas about ecological problems, human-nature relationships, and other broad ideas about how the world works. The next section, therefore, turns to the concept of worldviews, which provides a way to understand and analyze these underlying frameworks and their role in reasoning about SSIs.

Worldviews as interpretive lenses

Students enter the classroom with structured ways of making sense of the world that shape how they notice, interpret, and evaluate information (Bossér & Lindahl, 2019). These "interpretive lenses" are often referred to as "worldviews" (Goldberg, 2009; Koltko-Rivera, 2004). A worldview influences what a person sees as important or irrelevant, acceptable or unacceptable, good or bad. In higher education, this means that students' reasoning about environmental SSIs is shaped not only by the ecological knowledge they acquire, but also by deeper frameworks of beliefs and values that guide how they process that knowledge. This

section defines what is meant by worldview in the context of environmental SSIs and explores the frameworks that scholars have developed to study them.

Defining worldview for environmental SSIs

Across the natural and social sciences, scholars have proposed different ways of conceptualizing worldviews (Table 1.1; see Koltko-Rivera (2004) and Mifsud & Sammut (2023)). Broadly, most definitions agree that worldviews include beliefs about what is real (ontology), how we know (epistemology), and what matters (values/ethics). The Integrative Worldview Framework (IWF) offers a systematic attempt to operationalize worldviews into five dimensions (ontology, epistemology, axiology, anthropology, and societal vision) and to distinguish among four recurring worldview types in Western (i.e., Global North) societies: traditional, modern, postmodern, and integrative (de Witt et al., 2016). These categories have been shown to correlate with people's stances on climate change, sustainability, and other global challenges, demonstrating the powerful role of worldviews in shaping environmental concern and behavior (de Witt et al., 2017; Hedlund-de Witt, 2012)

Researchers focusing more narrowly on environmental issues have tended to conceptualize "environmental worldviews" in terms of attitudes and behaviors (Table 1.1; see Cruz & Manata, 2020 for an exhaustive list). These frameworks often emphasize whether individuals hold anthropocentric versus ecocentric orientations, how they value nonhuman life, or how supportive they are of conservation and sustainability initiatives. While they are useful for capturing connections between beliefs and pro-environmental behavior, they often oversimplify the deeper interpretive structures that the broader worldview literature highlights. However, both levels of conceptualization are important: environmental attitudes reflect specific

applications of broader worldviews, while the worldviews themselves provide the background frameworks that condition how environmental issues are understood and acted upon.

Worldviews actively shape how individuals process information (Figure 1.1). In environmental SSIs, this influence could appear through motivated reasoning, or the tendency to interpret information in ways that protect one's existing beliefs, values, or group identity (Epley & Gilovich, 2016). For example, in discussions about wolf reintroduction in the Rocky Mountain West, a student from a ranching family may approach ecological evidence showing ecosystem benefits with skepticism because accepting that evidence would conflict with their identity and community values. Here, the student's worldview drives them to favor interpretations that reduce psychological or social tension. A common manifestation of motivated reasoning is confirmation bias. Confirmation bias is the selective search for and use of information that supports one's prior beliefs while disregarding or downplaying contradictory evidence (Nickerson, 1998). Using the same example as above, a student may cite local news reports and ranching association statements about livestock losses while ignoring peer-reviewed ecological studies showing trophic effects that benefit the broader ecosystem. In this case, the worldview not only motivates skepticism but also directs the student's attention toward confirming sources of evidence. While these examples illustrate how worldviews operate as filters in SSI reasoning, their impact in higher education also depends on how stable or fluid students' worldviews are.

Worldviews in Emerging Adulthood

Worldviews are often described as relatively stable belief systems that change only slightly across adulthood; however, this is not the case for most college students (Poulin & Cohen Silver, 2008). Most undergraduates are "traditional"-aged (roughly 18-24), so the concept of emerging adulthood fits a large share of the students we teach (Renn & Reason, 2021).

Emerging adulthood is a stage of life when students attempt to develop autonomy while questioning or forming their beliefs about how the world works and their place within it (Arnett, 2000). For traditional undergraduates, these shifts are tied to common life changes, such as living away from home for the first time, starting jobs, and forming relationships (Arnett, 2007). Compared to older adults, students in this stage may also face added pressures of unstable housing and financial insecurity while balancing coursework and well-being. Emerging adulthood therefore presents affordances, both opportunities and risks, that help explain why worldviews in this age group may be especially fluid (Nelson, 2021).

Several studies have examined the extent to which students' worldviews change over time and the factors that influence these shifts. For example, one study of 168 undergraduate students explored how major life events impacted different aspects of their worldviews, including theistic (i.e., religion and suffering) and nontheistic (e.g., luck, self-worth, randomness) beliefs (Gutierrez & Park, 2015). The authors found that about 77% of students experienced a shift in at least one aspect of their worldview between the start and end of the term, with religious beliefs shifting the least. Similarly, stressful experiences have been shown to weaken some beliefs, such as benevolence or self-worth (Poulin & Cohen Silver, 2008), and at times lead students to conform more strongly to religion or, in rare cases, renounce it altogether (Exline et al., 2011). Yet, these same experiences can trigger positive transformation. Research on posttraumatic growth of college students shows that difficult events may alter their worldviews following intentional reflection (Triplett et al., 2012). While these findings highlight the role of major life events in shaping students' worldviews, they are not the only drivers of change.

Everyday experiences of college life, such as meeting peers with diverse backgrounds and engaging with new ideas in class, can also prompt students to reconsider or renegotiate their beliefs (Nelson, 2021). From a sociocultural perspective (Lantolf, 2000), identity develops through interaction with others, and these daily exposures may act as small but cumulative experiences that shape worldview. For example, encountering classmates who practice different faith traditions may lead some students to actively reexamine their religiosity and spirituality (Hill, 2011; McNamara Barry et al., 2010). Similarly, exposure to varied cultural norms or disciplinary approaches can broaden students' sense of what counts as valid knowledge or moral reasoning. Therefore, ordinary college transitions, like living with new roommates or taking courses outside of one's major, can be just as powerful as dramatic life events in shaping students' interpretive lenses.

Empirical patterns in undergraduate students' views of human-nature relationships

Undergraduate students enter ecology classrooms with diverse ways of thinking about the relationship between humans and the natural world (Cobern, 1993). Research shows that students often hold mixed or even contradictory ideas (Liu & Lin, 2014a). For instance, many simultaneously view humans as part of nature, as having authority over nature, and as being responsible for protecting it. Even students who express generally pro-ecological views can shift their stance depending on the issue being discussed. This variability means that reasoning about SSIs is not only influenced by ecological concepts students are learning about but also the orientations they already bring with them to the classroom. These orientations may help frame the problem before any argument or evidence is considered, which might explain why students reach different conclusions even when faced with the same ecological data (Casper et al., 2021).

Alongside these human-nature orientations, students often rely heavily on science-centered ways of interpreting environmental issues. Studies suggest that many undergraduates express strong confidence in science and technology, seeing them as primary tools for addressing environmental challenges (Liu & Lin, 2014b, 2018). At the same time, they may hold naïve or partial ideas about ecological systems. For example, some describe the "balance of nature" as a fixed state, not recognizing the dynamic qualities of ecosystems (Ergazaki & Ampatzidis, 2012; Zimmerman & Cuddington, 2007). These assumptions influence how students interpret evidence and evaluate competing explanations. Whether students see ecosystems as stable or dynamic, or science as objective or value-laden, their underlying beliefs shape what they perceive as persuasive. Thus, students' views of nature and of knowledge, both core elements of worldviews, interact to guide their reasoning about SSIs.

Another common pattern is the way students mentally model the environment. When asked to explain or draw representations of ecological systems, many undergraduates list species, places, or problems rather than the connections between them (Gal et al., 2023; Liu & Lin, 2015). These object-based models show that students often think of the environment as a set of separate parts instead of an interacting system. As a result, they may struggle to explain relationships, feedback, or human-environment interactions, which are central to ecological literacy and to SSI reasoning (Klemow et al., 2019). However, when students develop systems-based models, they also report greater environmental concern and emotional connection (Liu & Lin, 2015). Similarly, Gal and colleagues (2023) found that students who learn to include both social and ecological factors in their thinking become better at seeing how local actions connect to larger environmental processes. These findings suggest that promoting systems thinking is

both a way to support ecological understanding and strengthen personal connection students feel toward sustainability challenges.

Recent work has aimed to measure how students think about the links between humans and ecosystems. Casper and colleagues (2021) created a continuum of human-ecosystem conceptions that range from viewing humans as separate from nature to seeing them as integral parts of ecological systems. Progress along this continuum is associated with more ecological literate forms of reasoning, where students understand that humans both shape and are shaped by ecosystems.

Cultural background and experiences also shape how students' reason about environmental issues. Balgopal and colleagues (2012, 2017) found that when students write about local environmental issues, they draw on different types of evidence depending on their disciplinary and cultural contexts. Biology majors tended to emphasize scientific or technological solutions, while Tribal College students were more likely to reference moral, community-based, or cultural perspectives. These differences suggest that students' conceptions of human-nature relationships and tied to their broader ways of knowing and valuing the world.

The resources students draw on in SSI reasoning

Students' arguments about SSIs are built from resources they can access and legitimize in the moment. These include lived experiences, values and moral commitments, disciplinary knowledge, skills for evaluating evidence, social networks and mentors, media narratives, and broader cultural narratives. Several frameworks make sense of this repertoire. Here we briefly assess four common approaches (Funds of Knowledge, Science Capital, SEE-SEP, and Socioscientific Capital (SSC)) and explain why we adopt SSC as our organizing construct for the synthesis that follows.

Funds of Knowledge (FoK)

The Funds of Knowledge (FoK) framework offers a valuable starting point for examining the resources students bring to SSI contexts. Originating in sociocultural and anthropological studies, FoK emphasizes the historically accumulated, culturally developed knowledge that students acquire through their households and communities (González & Moll, 2002; Moll, 2006). In science education, FoK has been used to design instruction that connects students' lived experiences to academic content, making science more accessible, meaningful, and equitable (Barton & Tan, 2009; Denton & Borrego, 2021). For instance, a student from a farming background may have practical knowledge of soil management, irrigation, or pest control that enriches classroom discussions on ecology and agriculture.

While FoK has been instrumental in shifting educators' attention toward students' cultural and community resources, it is not fully equipped to capture the complex mix of resources students use when reasoning about SSIs. FoK primarily focuses on interpersonal and cultural knowledge, often overlooking influences such as media exposure, professional experiences, or societal discourses that shape students' thinking (Chang Rundgren & Rundgren, 2010). These limitations have led researchers to call for more comprehensive frameworks that can integrate a broader range of knowledge sources and better reflect the complexity of socioscientific reasoning (Cian, 2020; Klaver et al., 2023; Zeidler & Sadler, 2023).

Science Capital

The concept of science capital builds on sociocultural theories of learning, such as FoK and Bourdieu's theory of social reproduction (1977), by examining how students' science-related

experiences are recognized and valued within formal education. However, unlike FoK, which includes the full range of cultural and community-based knowledge students develop, science capital focuses specifically on resources tied to science (Archer et al., 2012). These resources include what students know about science, who they know in scientific communities, how they talk about science at home, and whether they see science as relevant to their everyday lives. Students with higher science capital tend to express stronger science identities and are more likely to draw on scientific evidence and reasoning in decision-making contexts (DeWitt et al., 2016). By emphasizing how science-related resources are shared and valued, science capital helps explain why some students feel more comfortable and confident in science than others. It also shows how identity and access shape whether students see science as meaningful and as a trusted way of understanding the world. These ideas make the framework helpful for studying how students access and recognize science-related resources when reasoning about SSIs.

However, science capital has limitations when applied to socioscientific reasoning. First, science capital was originally developed to explain participation and aspiration in science careers (Archer et al., 2015). It gives less attention to how science-related resources are used when reasoning about complex-value laden problems. Further, it has been argued that the framework emphasizes the "science" while neglecting the "socio" aspects that define SSIs (Klaver et al., 2023). Science capital privileges institutional and academic forms of knowledge, while overlooking local, cultural, and experiential ways of knowing that students may also draw upon. Moreover, it focuses on individual participation rather than argumentation, providing no explanatory power for understanding how students might integrate different forms of evidence into decision-making. For these reasons, its scope is too narrow for examining students' SSI reasoning in ecological contexts.

SEE-SEP

The SEE-SEP model was developed to integrate the cross-disciplinary dimensions of SSIs with their four features (complexity, multiple perspectives, ongoing inquiry, and skepticism) into a single framework for how people reason about SSIs (Chang Rundgren & Rundgren, 2010). In SEE-SEP, six subject areas or "domains" (Sociology/Culture, Environment, Economy, Science, Ethics/Morality, and Policy) are linked to three aspects of reasoning (Knowledge, Values, and Personal Experience). In practice, this model helps researchers and instructors to identify what domain a claim draws on (e.g., science vs. policy) and how it is framed (knowledge, values, or experience). For instance, studies using SEE-SEP have informed the design of classroom SSI activities (Christenson et al., 2014). In an analysis of students' informal arguments across four SSIs, Christenson and colleagues (2012) found that science and non-science majors differed in the kinds of evidence they used, and that values-based justifications appeared more often than knowledge-based claims. Despite its utility, SEE-SEP mainly maps observable claims in students' arguments, which raises questions about what it misses.

Although SEE-SEP is framed as holistic, it is largely descriptive. The model links domain-aspect pairs but offers limited insight into where knowledge comes from (e.g., coursework, media, family, work) or whose values are expressed. Additionally, the limited studies that have used the model have shown clear patterns that are not explained as potentially external influences, such as the task design rather than students' actual repertoires. Finally, applying 18 codes can be labor-intensive and may limit its practicality for larger studies or classroom use.

Socioscientific Capital (SSC)

The Socioscientific Capital (SSC) framework offers a more comprehensive way of describing the resources students bring to socioscientific reasoning. SSC was developed to broaden earlier models by tracing what resources appear in students' arguments, where those resources come from, and how they are activated in context. SSC is organized into three types of resources (Figure 1.2): internal (students' own experiences, values, attitudes, beliefs, knowledge, and skills), external (people and places students learn from – family, peers, community, media, school), and meta-level (larger cultural frames and dominant narratives that set the background for sense-making).

There are many reasons why this framework is particularly useful for examining students' use of resources for SSI reasoning. First, SSC does not privilege any single type of knowledge. Whereas FoK emphasizes community-based or cultural knowledge and science capital prioritizes academic and institutional forms of science knowledge, SSC integrates both, recognizing that scientific, experiential, and cultural resources all shape reasoning. Second, SSC situates reasoning within broader social structures, acknowledging that access to and legitimacy of resources are shaped by context, such as the dominant frames in society. This allows researchers to trace how these societal structures enable or constrain which resources students use. Third, SSC explicitly includes values, beliefs, and attitudes as integral resources for reasoning, components that align closely with worldview dimensions described by de Witt's (2016) Integrative Worldview Framework and that scholars have highlighted as essential for understanding SSI reasoning (Fang et al., 2019; Rudsberg & Öhman, 2015).

LINKING THE CONSTRUCTS

With the core constructs now defined, this section integrates them into a layered model that specifies the mechanisms linking culture, person, and practice in students' SSI reasoning

(Figure 1.3). The model extends existing frameworks by illustrating how dominant societal narratives filter down to shape personal worldviews, which in turn influence the kinds of resources students perceive as legitimate or relevant when reasoning about environmental SSIs. These resources are then expressed behaviorally through the claims, evidence, and justifications that students articulate in their reasoning. Although the model is presented as a hierarchy, the relationships among levels are reciprocal. Meta-level cultural ideologies shape worldviews, which filter and weight SSC, but students' reasoning and discourse can also reproduce, reinterpret, or contest those same narratives. The sections that follow trace each of these pathways.

Meta-level Resources (society) → Worldviews (individual)

Environmental philosophers have long argued that modern ecological crises are rooted in deep-seated worldviews that structure how humans relate to nature (Dunlap & Van Liere, 1984; Hedlund-de Witt, 2013; Swan, 1971; Van Opstal & Hugé, 2013). These worldviews arise from broader ideological systems that circulate within societies. One of the most influential of these is the industrialized dominant social paradigm (DSP), or the set of beliefs and values that emphasize economic growth, technological optimism, individualism, and human dominance over nature, as seen in Western societies or other "developed" nations (Bogert et al., 2022). Within this paradigm, environmental degradation is often framed as a technical challenge to be solved by innovation, rather than as a cultural or moral issue requiring shifts in values or behavior.

Through processes of socialization, such as schooling, media exposure, and everyday discourse, these meta-level ideologies become embedded within individuals' personal meaning systems (Lave & Wenger, 1991; Vygotsky, 1980). Students, for instance, may encounter messages that reinforce human exceptionalism in broader society and in the way that science is

often taught as objective and value neutral (Koster & de Regt, 2020). Over time, these recurring messages shape how students understand authority and what kinds of solutions seem reasonable when reasoning through SSIs. Betz and Coley (2022) found that this human-exceptionalist lens is especially common among undergraduates, who tend to view humans as uniquely responsible for causing climate change but also as uniquely protected from its consequences. Worldviews, therefore, can be understood as individual-level expressions of these broader ideological systems - personalized interpretations influenced by students' experiences, cultural backgrounds, and education.

Worldviews (individual) → SSC (resource)

Worldviews shape how individuals interpret and legitimize different kinds of knowledge. In the context of SSIs, these interpretive lenses determine which resources (e.g., scientific, experiential, cultural) students consider relevant or trustworthy. For instance, a student who holds a modern or technocentric worldview may privilege data-driven solutions while another whose worldview emphasizes interdependence with nature might draw on cultural knowledge. These differences illustrate how worldviews might filter the activation of SSC. Understanding how worldviews influence the resources students draw upon is critical because it reveals why students with similar disciplinary backgrounds may reason in different ways. Worldviews may explain how individuals determine the credibility and relevancy of information when they make decisions. Without accounting for these filters, differences in reasoning may be misinterpreted as differences in knowledge rather than differences in worldviews.

SSC (resource) → Reasoning (behavioral)

Once a student activates their worldview to make meaning of environmental SSIs, they draw on SSC to help them reason and make decisions. These resources become visible in the

claims and evidence that students articulate when constructing arguments. Reasoning can thus be viewed as the behavioral expression of SSC: what students draw upon and how they combine it to make sense of complex problems.

Patterns in students' reasoning reveal which resources were activated during sensemaking. For example, when a student uses ecological concepts to justify dam removal, but frames the argument entirely in economic terms, it suggests that meta-level narratives emphasize utilitarian values continue to shape their reasoning. Conversely, when students integrate multiple forms of evidence (e.g., ecological, political, cultural, experiential), they demonstrate reasoning that transcends these dominant frames. Importantly, reasoning also feeds back into the broader system. As students articulate, share, and defend their arguments, they may reinforce or contest meta-level narratives. Thus, reasoning is both shaped by culture and serves as a mechanism for reshaping it - reproducing or challenging the ideological assumptions that originally shaped students' worldviews and resource use.

Rapid environmental change has made clear that solving ecological problems depends as much on how people make decisions based on what they know. Scientists and natural resource managers must navigate issues that are ecological and technical as well as social, ethical, and political. Because universities prepare many of the people who will face these challenges, ecology and natural resource management (NRM) programs play a central role in shaping how future professionals and decision makers (e.g., voters, taxpayers) learn to interpret information, weigh evidence, and act within complex decision systems. This dissertation examines how students develop and apply decision-making competencies across educational stages (i.e., undergraduate and graduate). Guided by the Values-Rules-Knowledge framework, I examine

how students draw on different forms of understanding, norms, and authority when responding to social-ecological problems.

DISSERTATION ORGANIZATION

I entered my doctoral program with an interest in how people make meaning and think about the environment, initially planning to study ecological literacy among undergraduate students. However, my experiences as both an ecologist and science education researcher continually drew me toward questions of identity – specifically, how students come to see themselves as ecological thinkers and practitioners. Early in my coursework, I began to notice that many studies of ecological literacy emphasized content knowledge or technical skill development, but said little about how students integrate personal beliefs, cultural influences, and disciplinary norms into their reasoning. These observations inspired me to examine ecological literacy through the lens of identity, focusing on how students' worldviews, experiences, and reasoning interact across different stages of higher education.

The direction of this dissertation emerged during my enrollment in a qualitative research methods course that required me to conduct a grounded theory study of a phenomenon I was currently immersed in. At the time, I was enrolled in a NRM course where my classmates and I were frequently asked to reflect on our positionality within the field. Through these discussions and reflections, I noticed that many peers struggled to reconcile their own identities and knowledge of NRM with the relational and collaborative nature of community-based work. With my instructor's approval, I conducted interviews and collected field notes to explore this phenomenon. The resulting grounded theory, presented as Chapter 4, identifies how graduate students experience and respond to identity tensions that arise from misalignments between their personal worldview, prior experiences, and professional expectations. From this study, I

developed a preliminary model of professional identity development consisting of three dimensions: identity perception, identity response, and long-term outcomes. This early work became the conceptual foundation for my dissertation and deepened my interest in how students integrate personal and disciplinary ways of knowing.

During my grounded theory study (Chapter 4), I began to wonder how earlier stages of ecology education might reveal similar identity processes. My initial research in the NRM course showed that graduate students were negotiating tensions between their personal beliefs and the professional expectations of their field. This led me to ask whether such tensions might begin forming much earlier, when students are first learning to reason about social ecological issues in undergraduate classrooms. Around this time, I began collaborating with my colleague, Dr. Marit Bogert, whose dissertation work at Vrije Universiteit Amsterdam focused on individuals' worldviews and their influence on understanding global environmental challenges. Marit introduced me to the Integrative Worldview Framework and shared how it was being applied to both Dutch and American contexts. Our conversations helped me recognize that students' reasoning about environmental issues can be shaped by the assumptions and values embedded in their worldviews. This collaboration motivated the design of the remaining empirical chapters (2 and 3).

Chapters 2 and 3 were carried out in an introductory ecology course at Colorado State University, taught by one of my committee members, Dr. Paul Ode. At the time, I was serving as the graduate research assistant on a federally funded National Science Foundation (NSF) project (Grant # 2235378) for which he and my advisor were principal investigators. The NSF study examined how active learning strategies can enhance students' ability to interpret and engage with primary scientific literature. Each week students read a peer-reviewed article aligned with

the ecological concepts being discussed in class. Building on this structure, we designed and implemented an additional research component to collect data for my dissertation. For each weekly reading, we developed an environmental SSI question that prompted students to apply the concepts from the paper to a real-world context. These written responses became the basis for my analyses in Chapters 2 and 3.

Chapter 2 examines the relationship between students' worldviews and the ways they express them in written reasoning about environmental SSIs. I used the Integrative Worldview Framework to classify students into distinct worldview clusters and then analyzed their worldviews expressed in written arguments to check for alignment. Three patterns of students emerged: Anchors, who consistently expressed their classified worldviews; Adapters, who primarily expressed a different worldview than the one they were classified; and Explorers, who expressed multiple worldviews in their writing.

In Chapter 3, I apply the socioscientific capital (SSC) framework to examine the types of resources students draw on when reasoning about these same issues. Students' responses were coded for the internal, external, and meta-level resources they used. In characterizing their resources, I found that students most often drew on internal and academic forms of knowledge, while a personal or locally relevant prompt encouraged more value-based and affective reasoning, and thus more internal resources (i.e., values, beliefs, attitudes). This suggests that the role students take on when they reason through SSIs may influence which resources they view as relevant.

Finally, in Chapter 5, I present a theoretical synthesis that draws on the concepts presented in Chapters 2 and 3. Here, I propose an integrative model that links meta-level narratives, worldviews, SSC, and reasoning. The model depicts how dominant societal narratives

and ideologies (meta-level) shape individuals' worldviews, how these worldviews influence which resources are activated as SSC, how those resources inform students' reasoning about environmental SSIs, and how reasoning can, in turn, reinforce or challenge the broader meaning systems from which it emerges.

POSITIONALITY STATEMENT

As a researcher trained in both ecology and science education, I occupy an interdisciplinary space between the natural and social sciences. My background as a field ecologist has taught me to value data and careful observation. My training in education and qualitative research, however, has helped me to see that culture, language, and power also shape how knowledge is created and shared. Further, as a U.S.-based scholar who has spent most of my academic life in research universities, I acknowledge that this background gives me certain privileges while also limiting my perspective. It motivates me to think about how traditions influence the way science is taught and who feels included in it.

My understanding of knowledge has changed over time. When I began graduate school, I believed that science was the main way to know and explain the world. Through my teaching and study of science education, I came to see that knowledge is built through relationships and experiences and not just experimentation. My interest in students' worldviews has been driven by my own efforts to reconcile ways of knowing. I now believe that many ways of knowing can coexist, which aligns with the epistemology domain of my IWF worldview: postmodern. My own worldview affects how I interpret students' writing and reflections. I try to remain aware of these influences by reflecting on how my experiences as an ecologist and educator shape my interpretation.

TABLE

Table 1.1 Broad and environmental worldview frameworks relevant to environmental SSIs. This table compares two main paths of worldview research. The top half summarizes broad worldview frameworks, which conceptualize worldviews as underlying systems of meaning. The bottom half highlights environmental worldview measures, which focus more narrowly on attitudes and values related to human-nature relationships.

Framework/Measure	Dimensions	Source
Broad Worldviews		
Integrative Worldview Framework (IWF)	Ontology, Epistemology, Axiology, Anthropology, Societal Vision	(de Witt et al., 2016)
Logico-Structural Model	Self, Nonself, Classification, Relationship, Causality, Time, Space	(Cobern, 1996)
Worldview [conception unnamed]	Symbolic universes, social axioms, moral frameworks, deep stores	(Sammut et al., 2022)
African Worldview	Nature, Interconnection/Interdependence, Water, Time, Ubuntu, Identity, Taboo, Culture	(Keane, 2008)
Environmental Worldviews		
New Environmental Paradigm (NEP)	Limits to growth, Nature's balance, Anti-anthropocentrism	(Dunlap & Van Liere, 1978)
New Ecological Paradigm (revised NEP)	Limits to growth, Anti-anthropocentrism, Nature's balance, Human exceptionalism, Ecocrisis	(Dunlap et al., 2000)
Value Orientations Scale	Egoistic, Social-altruistic, Biospheric	(Stern et al., 1993)
Anthropocentric and Ecocentric Attitudes Scale	Anthropocentrism, Ecocentrism	(Thompson & Barton, 1994)
Environmental Concerns	Egoistic, Altrustic, Biospheric	(Schultz, 2001)

FIGURES

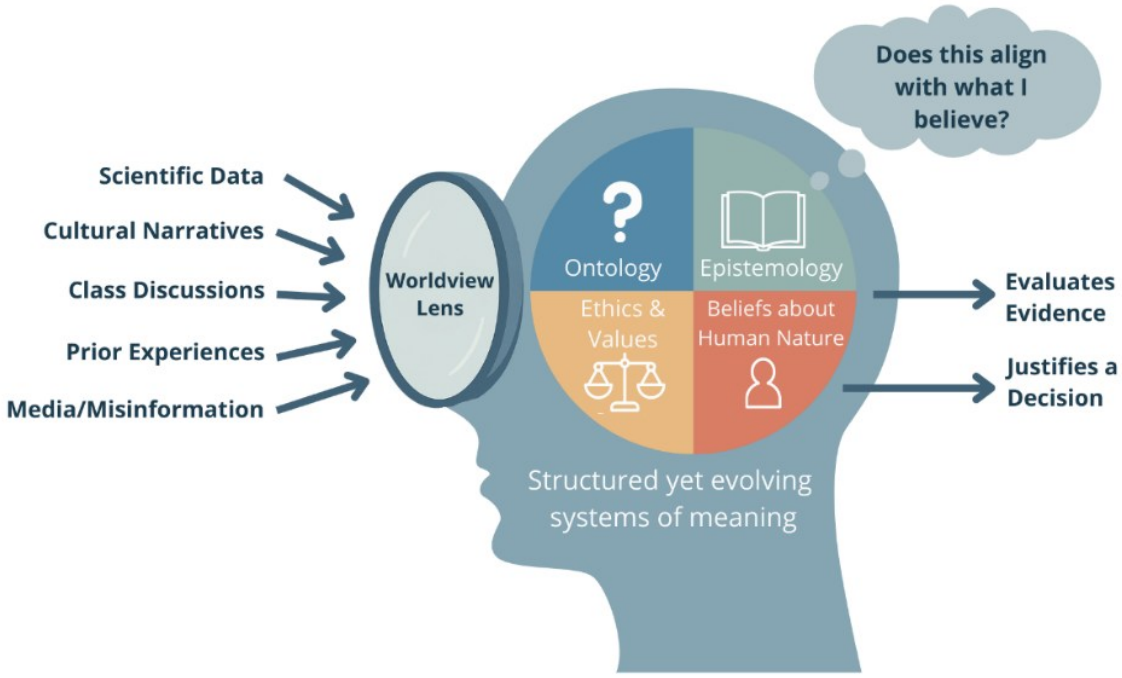

Figure 1.1 Undergraduate students' worldviews act as interpretive lenses as they evaluate various types of evidence (e.g., scientific data, narratives) and make decisions about socioscientific issues. Students' structured, yet evolving, systems of meaning are shaped by their ontology, epistemology, ethics and values, and beliefs about human nature.

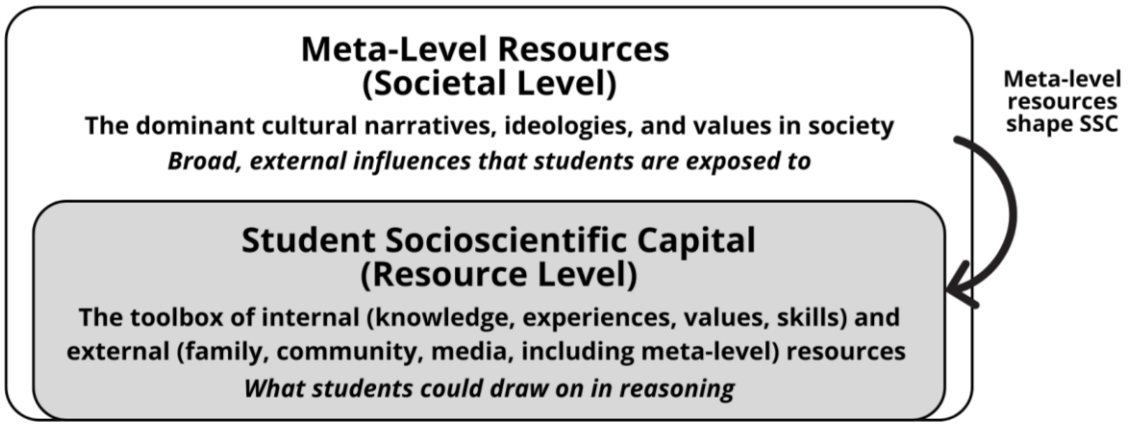

Figure 1.2 The Socioscientific Capital (SSC) framework conceptualizes the range of resources students bring to reasoning about SSIs (adapted from Klaver et al., 2023). Meta-level resources represent broad societal influences, such as dominant cultural narratives. Student socioscientific capital encompasses both internal resources, such as experiences and values, and external resources, such as community or academic knowledge, that shape what students can draw upon in reasoning. The arrow indicates the relationship between these levels, showing how societal contexts influence students' available resources.

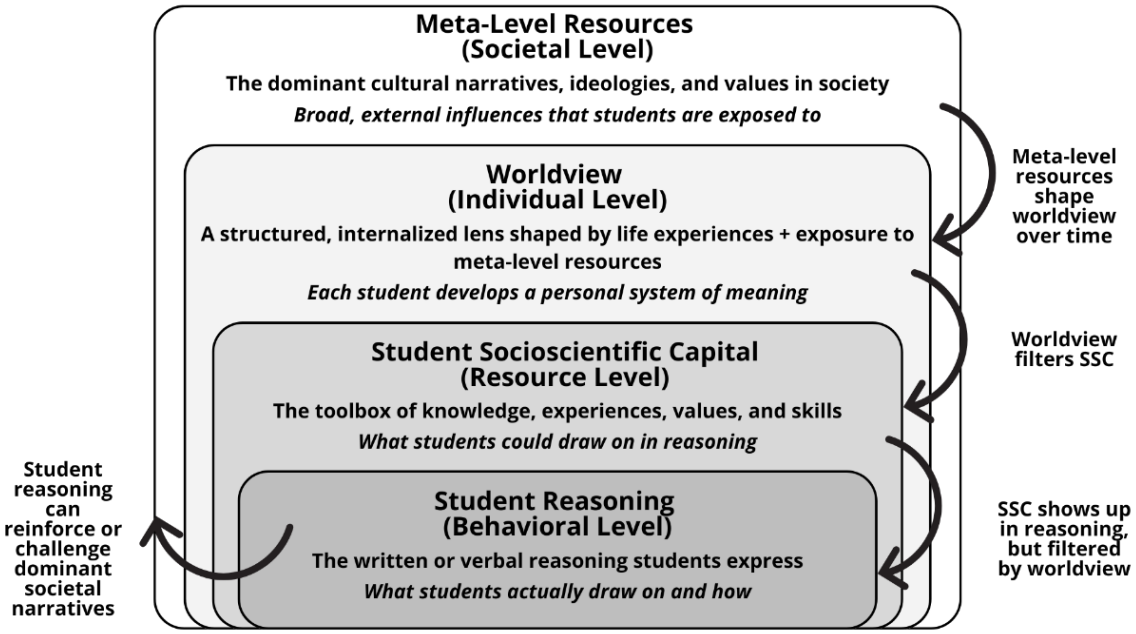

Figure 1.3 A layered model linking meta-level culture, worldview, socioscientific capital, and reasoning in environmental socioscientific issues (SSIs). At the meta-level (societal), dominant cultural narratives and values shape the ideas and assumptions that individuals are exposed to. These narratives inform the worldview (individual) level, where students internalize and reinterpret societal messages to form personal systems of meaning. In turn, worldviews shape the socioscientific capital (resource) level by filtering what knowledge, experiences, and values students view as relevant to use when reasoning. Finally, the student reasoning (behavioral) level represents the outward expression of these filtered resources though the claims and evidence students produce in written or verbal arguments. Arrows between layers indicate interaction: while culture shapes worldview and resource use, students' reasoning and discourse can also reinforce, reinterpret, or challenge dominant societal narratives.

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CHAPTER 2

INTRODUCTION

Undergraduate ecology courses increasingly challenge students to address complex social-ecological problems that cannot be solved through scientific knowledge alone (Boon & Van Baalen, 2019; Johnson & Mappin, 2005; Lewinsohn et al., 2015; Willson et al., 2023). Issues such as land-use practices and agricultural runoff require reasoning that integrate ecological processes with the social context in which it occurs (Balgopal et al., 2012; Gray et al., 2012; Ives & Kendal, 2014; Jones et al., 2016). To support such integrative social-ecological reasoning, many instructors organize instruction and assessment around ecological literacy frameworks that emphasize systems thinking and scientific inquiry (Berkowitz et al., 1997; Cherrett, 1989; Jordan et al., 2009; Klemow, 1991; Odum, 1992; Powers, 2010). Yet, these frameworks offer limited guidance for incorporating students lived experiences, personal values, and beliefs systems into how they interpret problems and justify solutions (McBride et al., 2013). Consequently, students have fewer structured opportunities to practice integrating scientific and nonscientific evidence, limiting their preparation for evidence-informed decision-making in social-ecological contexts[2]. This is important because students enrolled in ecology courses may choose to pursue further study or employment in environmental science fields, in which they might be expected to integrate multiple types of knowledge (Knight & Allan, 2021).

[2] We distinguish ecology from environmental science in scope and aims (Rana, 2013). It is unsurprising that ecology courses center ecological literacy (systems thinking, inquiry) rather than broader, applied frameworks more often emphasized in environmental science/studies. Because many students do not also take environmental science, ecology classrooms remain a practical context for connecting ecological principles with civic, policy, and ethical considerations.

One approach to support integrated reasoning is to embed argumentation within socioscientific issue (SSI) contexts (Henderson et al., 2018; Sadler, 2004). SSIs are open-ended problems that are grounded in both scientific and socially relevant evidence (Zeidler, 2014), and they are frequently used to increase the relevance of science curricula to students' lives (Chang Rundgren & Rundgren, 2010). The power of SSIs is that there are no clear right or wrong solutions to the problems that emerge, allowing students to focus on their own decisions and arguments, rather than to focus on answering "correctly" (Balgopal et al., 2017; Balgopal & Wallace, 2013). When reasoning about SSIs, students draw on their socioscientific capital (SSC): the collection of internal, external, and meta-level resources that inform how they learn, evaluate evidence, and make decisions, including integrating disciplinary knowledge learned in the classroom (Evagorou & Osborne, 2013; Klaver, Sins, et al., 2023; Moje et al., 2004). These resources can enrich students' reasoning by providing multiple lenses for evaluating evidence and proposing solutions (Högström et al., 2024). At the same time, they may generate tensions, such as when personal or cultural beliefs conflict with scientific explanations (Balgopal, 2014; Balgopal et al., 2021). As students engage in SSI-based argumentation, they might encounter and subsequently must navigate these tensions as they negotiate meaning across different ways of knowing (Patronis et al., 1999). The process of reconciling diverse resources, especially when those resources reflect deeply held beliefs, points to the importance of worldview as a foundational lens in students' reasoning. Hence, to understand how students make meaning of SSIs, it is essential to examine the role that worldviews play in students' reasoning during written argumentation activities.

Worldviews as Lenses for Socioscientific Reasoning

Worldviews are structured yet evolving systems of meaning that shape how individuals perceive, interpret, and respond to the world around them (Hedlund-de Witt, 2012) (Figure 1.1). While many conceptualizations of worldviews exist (Bruner et al., 2014; Cobern, 1996; Cruz et al., 2022; Gutierrez & Park, 2015; Jurin & Hutchinson, 2005; Lynam, 2019; Poulter et al., 2016), many are based on one or several of the following dimensions (Table 2.1): ontology, epistemology and knowledge, ethics and values, and human nature. As students reason through SSIs, their worldviews operate as interpretive lenses, guiding how they evaluate and integrate diverse funds of knowledge and justify decisions (Cobern, 1996; Jurin & Hutchinson, 2005). Manifestations of worldviews, such as the specific prior beliefs and biases that students bring to the classroom (also referred to as "intellectual baggage" by Zeidler 1997), influence how students interpret new information (Rundgren et al., 2016). When students are unaware of how their assumptions shape their reasoning, they may use motivated reasoning, favoring evidence that supports their existing beliefs while dismissing contradictory information to protect their sense of self or community values (Kunda, 1990). In doing so, they may exhibit confirmation bias by selectively seeking evidence that affirms their worldviews (Koslowski, 2013; Marsh & Hanlon, 2007; Nickerson, 1998). In the classroom, confirmation bias can shape how students justify their decisions, whether by overemphasizing personal value systems or disregarding evidence that challenges their preexisting beliefs (Epley & Gilovich, 2016). When these assumptions remain unexamined, biases can constrain learning and diminish the quality of argumentation (Wolfe et al., 2009). Conversely, when students explicitly reflect on their assumptions, often with instructor scaffolds, their arguments show more consistent use of evidence and a greater willingness to engage with alternative explanations (Bächtold et al., 2023).

The connection between confirmation bias and students' reasoning processes is relevant for how they apply rules of inference, or the standards they use to connect evidence to claims (Jimenez, et al., 2024). For example, one student might use empirical data as justification, while another might draw on religious or familial authority when making meaning of complex social-ecological issues. Inferential standards are deeply rooted in students' epistemological and moral assumptions, aligning closely with the worldview dimensions (Table 2.1). When confirmation bias influences the rules of inference students rely on, it may further impede their ability to see alternative viewpoints or consider other types of evidence (Wolfe et al., 2009). To examine these inference patterns systematically, we need constructs that characterize the underlying worldview orientations that shape them.

Several models have been developed to measure or describe worldview orientations related to environmental decision making (Bogert et al., 2022; Dunlap, 1980; Dunlap & Van Liere, 1978; Mayer & Frantz, 2004; Milfont & Duckitt, 2004; Schultz & Zelezny, 1999; Thompson & Barton, 1994). While useful, many of these models rely on binary or linear typologies (e.g., anthropocentric vs. ecocentric), which may oversimplify the pluralistic and hybrid nature of students' meaning-making frameworks (Hedlund-de Witt, 2012). In addition, the constructs in several commonly used scales are grounded in Western European and Abrahamic religions, potentially marginalizing other ways of knowing and relating to nature (Hedlund-de Witt, 2013). Also, these typologies often conflate vague or underdeveloped views with more intentionally integrated, complex perspectives, making it difficult to identify the depth of a person's worldview (Wilber, 2000). Some scales further focus narrowly on instrumental relationships with nature, overlooking spiritual or metaphysical dimensions that can influence environmental values and behaviors (Dietz et al., 1998; Thompson & Barton, 1994). In contrast,

the Integrative Worldview Framework (IWF) developed by Hedlund-de Witt (2014) offers a non-hierarchical model for characterizing worldview orientations across all dimensions (Table 1). The IWF has been used to explore cross-cultural differences in sustainability values (Hedlund-de Witt, 2014) and is relevant for educational research as it provides a quantitative measure of students' overarching patterns of meaning-making.

Although worldview frameworks like the IWF offer promising insights for educational research, scholars have raised important critiques about their application and limitations in classroom contexts (Hedlund-de Witt, 2012; Johnson et al., 2011). Even de Witt and her colleagues (2016) caution that the most nuanced typologies may inadvertently essentialize students' perspectives, particularly when they are shaped by intersectional identities. Moreover, in classroom settings, there is a risk of reifying worldviews, or treating them as fixed attributes, rather than recognizing them as fluid, context-dependent lenses that guide meaning-making (Matthews, 2014). Rather, worldviews develop through participation and interaction and are shaped by the social contexts in which learning occurs. These critiques align with broader theories of learning as situated social practice, in which knowledge construction is embedded in community participation (Lave & Wenger, 1991). From this perspective, students' worldviews evolving sets of beliefs that are reshaped through academic exercises prompting them to make decisions of complex SSIs. Such activities require students to reconcile different funds of knowledge, epistemic stances, and beliefs (Kelly & Takao, 2002).

Worldviews likely shape how students interpret evidence and construct arguments about environmental SSIs (Van Opstal & Hugé, 2013). Characterizing students' worldview orientations offers critical insight into their reasoning processes. Although many studies have examined how beliefs and values influence communication and behavior (Goldberg, 2009; Hornsey, 2021;

Kohler et al., 2019; Wilkens & Sanford, 2009), fewer have explored how worldviews, as broader systems of meaning, shape students' reasoning and written argumentation about SSIs. Recent work suggests that while students often rely on personal and cultural knowledge in reasoning, they do not always integrate it productively with scientific information in ways that strengthen the quality of their arguments, leading to shallow or inconsistent reasoning (Jimenez et al., 2024). These observations highlight the need for empirical descriptions of how worldviews appear in students' written arguments about SSIs (Kumar et al., 2024)

This study explored how undergraduate students incorporate their worldviews into written arguments about SSIs in an ecology course. Specifically, we examined the degree of alignment or misalignment between students' worldview orientations through a survey and the worldviews they expressed through their written justifications for decision-making regarding different environmental SSIs. By exploring this alignment, we aim to better understand how students negotiate their socioscientific capital, their worldviews, and new academic (i.e., ecological) knowledge to environmental SSI decision-making.

METHODS

We employed a mixed-methods design (Creswell & Creswell, 2017) to explore how undergraduate students' worldviews shape their written arguments about environmental SSIs. Data were collected through surveys, interviews, and course artifacts to examine the alignment between students' worldview orientations and the reasoning strategies they used to support environmental decision-making. This study was approved by our institutional ethics review board.

Study Context

This study was conducted in an upper-division, semester-long undergraduate ecology

course over two consecutive years (spring 2023, spring 2024) at a Land-Grant institution in the Mountain West region of the United States. The course introduced students to ecological principles, focusing on the relationships between organisms and their environments across scales, from individuals to ecosystems focusing on model-based reasoning and ecological theories. Topics explored in the class included biodiversity, energy flow, population growth, and species interactions. While the course emphasized fundamental ecological concepts, the instructor of the course sections studied also covered some environmental science examples (i.e., climate change, habitat fragmentation, designing nature reserves). There are several instructors across campus who teach this course, but data collected in this study from both sections were taught by the same instructor, ensuring consistency in course content and instruction. The instructor was trained as a community ecologist 35 years ago and had been teaching ecology courses for the past 23 years at the time of the study.

The course is required for several majors, both foundational (Biological Science, Zoology) and applied (e.g., Conservation Biology). Women were well-represented (69%) in this course, like life science majors at this institution. The student population also reflected the institution's demographic composition, which is predominantly White (69%) but includes representation of Hispanic/Latine (15%) and multiracial (5%) students**.**

Data Collection and Analysis

Survey

At the beginning of the semester, the instructor and students completed the IWF survey to assess their orientations across five dimensions: ontology, epistemology, axiology, anthropology, and societal vision. The survey (see Appendix 2.1) consisted of 17 items, each asking students to choose the worldview statement they agree with most and least (i.e., best-worst scaling). Each

item included one response option corresponding to each of the four worldview types: traditional, modern, postmodern, and integrative. Survey responses were used to classify the instructor and students into a dominant worldview category. Individuals whose responses showed high alignment across multiple categories were classified as having a "mixed" worldview.

Interviews

Students were invited to volunteer for a semi-structured interview following the survey. Interviews were conducted within the first three weeks of the semester and transcribed using OtterAI, after which transcripts were reviewed and verified before analysis. Interview questions explored students' perceptions of nature, human–environment relationships, and the kinds of knowledge they typically drew on in their academic work (e.g., scientific, personal, cultural, or professional). Interviews also probed whether and how students believed their worldview might influence their decision-making and engagement with course content (see Appendix 2.2 for interview protocol). The interview protocol was developed in alignment with the IWF and SSI reasoning literature to ensure that questions elicited students' worldviews and how their beliefs informed their reasoning about environmental issues. Interview transcripts were analyzed thematically (Braun & Clarke, 2006) to identify students' worldview orientations and reasoning strategies. Interviews were inductively coded. The analysis allowed us to better characterize how students' worldviews may have shaped their written arguments.

Homework Assignments

Throughout the semester, students completed a series of five written homework prompts designed to elicit their reasoning on environmental SSIs. Each prompt required students to adopt either a personal perspective (drawing on their own values or beliefs) or a professional

perspective (responding as an ecologist, city planner, or local volunteer). Prompts focused on five themes: species introduction, invasive species, pathogen spread, habitat fragmentation, and environmental management philosophical dilemmas (see Appendix 2.3 for full prompt list). All students within and across both sections responded to the same prompts. Student responses were analyzed qualitatively for the worldviews expressed in their reasoning. Coding was refined iteratively. Two researchers independently coded a subset of responses to establish interrater reliability, achieving 90% agreement, after which consensus was found during a final discussion. Subsequently, final coding was completed. Expressed worldviews for each student were examined across prompts to identify patterns in the alignment and consistency of worldview expression. These patterns were then quantified to describe the overall distribution of worldview expression types across the dataset. Trustworthiness was achieved through peer debriefing, and triangulation across surveys, interviews, and course artifacts.

RESULTS

A total of 225 students (spring 2023: 114; spring 2024: 111) participated in this study, providing responses across 5 homework assignments designed to explore students reasoning and decision-making on environmental SSIs. Among these students, 139 (62%) were classified as having an *integrative* worldview, 50 (22%) had a *postmodern* worldview, 11 (5%) had a *modern* worldview, and 4 (2%) had a *traditional* worldview (Figure 2.1). Some students (21, 9%) tied across multiple worldview categories and were classified as having a *mixed* worldview. For context, the course instructor was classified as having a *postmodern* worldview.

To explore how students' written arguments aligned with their classified worldview clusters, we examined patterns across multiple homework responses and identified three main themes: *Anchors, Adapters*, and *Explorers* (Table 2.2). *Anchors* (n=3) are the students whose

writing consistently aligned with their classified worldview orientation, suggesting a stable interpretive lens through which they made meaning of environmental SSIs. *Adapters* (n=116) wrote from a different worldview than the category in which they were classified but did so consistently across prompts. Finally, *Explorers* (n=106) drew from multiple worldviews across their responses and were not consistent. Cases of the three themes, *anchors, adapters,* and *explorers*, are presented below.

Anchors: Consistent Alignment Between Classified and Expressed Worldviews

For very few students (n=3), there was a clear and consistent match between their IWF-classified worldview and their reasoning. Across prompts, these students framed their arguments using language and values that were consistent with the beliefs and assumptions associated with their worldview orientation. Whether making decisions about invasive species or habitat restoration, they tended to use a stable lens, suggesting that their worldview meaningfully shaped how they approached reasoning about environmental SSIs in this course.

Ellie, a woman double-majoring in wildlife biology and journalism and who described herself as "*deeply spiritual*," was classified has having an integrative worldview. Her writing throughout the semester clearly reflected this alignment (Figure 2.2). She frequently emphasized the interconnectedness of ecological systems, the intrinsic value of species, and the importance of honoring both spiritual and cultural relationships with nature. For example, in response to a prompt on wolf reintroduction, Ellie wrote:

> *Another reason I support the reintroduction of wolves is to honor the indigenous tribes of the Ute, Arapahoe, and Cheyenne. Wolves are an integral part of their ways of living and a spiritual guide for these humans. To displace or remove the indigenous peoples and then the wolves feels inherently disrespectful. I feel to honor what has been taken, wolves, and their place on this land, as well as the spirituality they guide humans through, is really important. I have indigenous friends and wolf spirit is really big in their culture… it is gravely important [to me] as I really connect to the spirit of a wolf, and for the people that were displaced.*

Ellie's response integrates spiritual and cultural reasoning, expressing a worldview that recognizes humans as embedded within broader social ecological systems. Additionally, her language (i.e., "*honor*") frames these environmental decisions as matters of ethics and accountability.

When asked to reflect on the value of organisms, she again grounded her reasoning in spiritual and ecocentric terms:

> *I am a deeply spiritual person who is extremely connected to nature…I think humans are trying to play god against nature, rather than being ecocentric and trying to be co-harmonious. All organisms have intrinsic value, I am nobody to sit and determine the value of another living thing just because I have a developed frontal lobe*.

Ellie's statement aligns with an integrative worldview as she believes in nature's intrinsic value. She describes a moral imperative to live in harmony with the natural world.

In the final prompt on water scarcity, Ellie's reasoning drew on the same worldview orientation, even when the issue was framed through a practical and policy-focused lens:

> *I do believe that we have a deep synergy and connection to nature, because we are nature…In order for us to be able to find a way to solve an environmental issue that is affecting not just one group of people, but different races, nationalities, socio-economic groups, etc...we must also incorporate all those different perspectives as well*.

Here, the epistemology lens of the integrative worldview is notable: that environmental solutions must be holistic, inclusive of multiple perspectives, and rooted in respect for both human and non-human life.

Adapters: Consistent but Divergent Worldview Expression

About half of the students (n=116) expressed a different orientation than their classified worldview, even though their reasoning remained consistent across multiple assignments. This was the case for Della, a woman majoring in the natural sciences with a focus on K-12 education. Her IWF survey results classified her as having an integrative worldview, yet her

reasoning used in open-response homework assignments throughout the semester reflected a modern worldview (Figure 2.3). Across multiple prompts, she emphasized human responsibility for managing ecosystems, the role of science and technology in solving environmental problems, and a functional view of biodiversity. For example, when asked to reflect on the role of humans in ecosystem management, Della described humans as "*higher beings*" with an obligation to protect other organisms but emphasized that human intervention should be limited unless human actions caused the damage. Although she acknowledged in her response that ecosystems change naturally over time, which could have aligned with an integrative orientation, her framing of human responsibility remained anthropocentric, positioning humans as both superior and responsible for the natural world.

Della's anthropocentrism carried through her other responses. When reflecting on biodiversity loss, she argued that humans depend on ecosystem services provided by diverse organisms and that science and technology will be the leading solution to solve this issue. She wrote, "*Technology will be the most important player in resolving the water problems*," citing the Hoover Dam as an example of how technological innovation enabled human survival and Western expansion in the U.S. More broadly, when discussing conservation efforts, she similarly framed protection of natural spaces in terms of the benefits they bring to humans, such as for recreation.

From an interview with another student, a more nuanced version of the Adapter pattern emerged. In this case, the student's survey classification and interview responses aligned, yet her written responses consistently reflected a different worldview, except when given the opportunity to choose an option that explicitly matched her own. For example, Kiki was classified as Traditional on the survey and described herself in her interview as deeply religious.

She explained that what she learned in school and church often came into conflict, and that she managed this tension by separating the two domains, "*... what I've been taught ...growing up in church and versus school…[has been] conflicting,"* and to reconcile the conflict she "*separates*" herself from it.

This compartmentalization was evident in her homework responses, where she consistently expressed a modern worldview by relying on scientific evidence and authority (Figure 2.4). However, when presented with a prompt that asked students to choose among multiple worldview options and elaborate on their choice, she selected the traditional option and justified it in terms of her faith. This was the only written response in which her traditional worldview was explicitly referenced, highlighting how she maintained a boundary between her academic and religious lenses.

Explorers: Fluid or Contextual Worldview Expression

Finally, the other half of students (n=106) shifted between worldview orientations across prompts or even within a single response. They might blend scientific reasoning with ethical concerns or alternate between valuing ecological harmony and prioritizing human well-being. Rather than adhering to a consistent line of reasoning, these students navigated across different worldviews. Pippa's responses illustrate this phenomenon (Figure 2.5).

Pippa, a woman majoring in the natural sciences, was categorized as having a postmodern worldview based on the IWF. However, her reasoning throughout the semester reflected shifts between traditional, integrative, and modern orientations, even though all three writing prompts focused on the same general topic of invasion. Early in the semester, when asked to reflect on the ecological impacts of invasive species in the Mojave Desert, she indicated that invasive species disrupt the natural balance of the ecosystem, that their impact "*would not be*

good" and "*it would be better to remove them*." This response reflects a traditional worldview, one that emphasizes the preservation of ecological order and a clear boundary between native and invasive species.

But by the middle of the semester, when prompted to consider whether organisms have intrinsic value regardless of their nativeness or utility, Pippa wrote, "*I believe that all organisms have intrinsic value, and organisms should not be valued depending on solely if they are native, non-native or invasive.*" She further explained that "*no organism should be more important or more valued than other organisms because ecosystems need all different variations of organisms in order to survive… every organism involved, no matter the size of the role, is important*." In her response, she argued that while some organisms may appear more important at first glance, perhaps because of their size, visibility, or perceived usefulness, every organism plays a vital role in maintaining the overall health and balance of the system. Although her early-semester response framed invasive species as a disruption to ecological order that should be corrected, her later writing revealed her view of ecosystems as interconnected and non-hierarchical – indicators of an integrative worldview. At the end of the semester, her reasoning shifted once again, this time toward a modern worldview. When asked to imagine herself as a city planner balancing biodiversity and water scarcity, Pippa emphasized the role of technology and ecosystem diversity in supporting human needs:

> *I believe that humans need the ecosystem in order to survive and that the ecosystem needs to be diverse to provide maximum resources... I also do believe that technology is always adapting and new technology is consistently being created... I think one day in the future there will be technology to help keep ecosystems from deteriorating and help them flourish even more.*

Her response centered on ecosystem health, human dependence, and technological advancement, prioritizing innovation as solutions to environmental problems. This way of reasoning, also

referred to as “techno-optimism” (Ribeiro & Soromenho-Marques, 2022), was different from her earlier arguments that nature has ideal states or is dynamic. Rather than focusing on what is best for ecosystems or valuing all organisms equally, she now framed her thinking around how ecosystems benefit humans and how technology might be used to maintain or even enhance those benefits. Pippa’s change (or exploration) in reasoning throughout the semester might reflect an evolving worldview, or a desire to consider multiple sides of an issue.

Another variation of the Explorer pattern emerged in cases where students’ worldview classifications aligned with their interview responses but not with their written responses to homework. For example, Thea was classified as having an integrative worldview through the survey and consistently described herself in her interview as weaving together science and spirituality. She spoke of nature as “*a cross between science and the hand of God*” and emphasized interconnectedness of humans and ecosystems. She also reflected openly on the tensions she experienced between her spiritual values and the scientific reasoning emphasized in her courses, noting that she often felt pulled between her beliefs and her recognition that quantitative evidence is necessary for solving environmental problems.

Despite this presumably stable integrative lens, Thea’s written responses alternated across modern, integrative, and traditional orientations (Figure 2.6). In one prompt she emphasized divine guidance as the foundation for environmental stewardship, reflecting a traditional worldview. In another, she draws on different forms of evidence (science, personal, and cultural) to propose alternatives to bird feeders that would both reduce diseases risk and support human enjoyment of nature, illustrating an integrative lens. In yet another, she supported wolf reintroduction in Colorado by appealing to state management

efforts and the scientific consensus regarding predator-prey dynamics, a clean example of modern reasoning.

DISCUSSION

This study examined how undergraduate students' worldviews, classified using the Integrative Worldview Framework (IWF), aligned with the worldviews expressed in their written arguments about environmental socioscientific issues (SSIs). Our findings reveal that students' worldview expressions are neither predictable nor fixed. While surveys provided useful baseline classifications, written responses uncovered distinct patterns (Anchors, Adapters, and Explorers) that illustrate how worldviews are expressed dynamically in classroom contexts (Table 2.2).

Anchors, like Ellie (Figure 2.2), provide strong evidence that worldviews can act as stable interpretive lenses, as their writing consistently aligned with their survey classifications. This pattern supports prior claims that worldviews shape how individuals reason about environmental issues (Hedlund-de Witt, 2013, 2014; Kahan et al., 2012; Van Opstal & Hugé, 2013). Although no studies to our knowledge have explicitly compared worldview classifications with patterns of reasoning, research has shown that some students consistently employ the same mode of informal reasoning across multiple SSI scenarios (Sadler & Zeidler, 2005). Likewise, Klaver et al. (2023), found that students draw on relatively durable internal resources (such as values, beliefs, and knowledge) when engaging with SSIs. These findings reinforce the claim that, for at least some students, worldviews provide a consistent lens for reasoning. Yet, the other two patterns we observed, Adapters and Explorers, demonstrate that worldview expression is often more complex.

Adapters, like Della (Figure 2.3), consistently wrote from a worldview different from their classification. Three probable explanations for this phenomenon relate to limitations of the

instrument we used (i.e., IWF survey). First, surveys are imperfect. Although the IWF is validated, it still relies on self-reported, and in this case closed-response, items that may not fully capture how a student reasons in practice. Therefore, it is possible that Della's "true" worldview orientation is closer to modern, which aligns with her consistent writing, while the integrative classification from her survey is simply a misclassification. Second, the survey taps into beliefs and self-concept, while the written assignments focus on practices and discourse. The mismatch could be less about misclassification and more about how each method measures different dimensions of worldview. In other words, Della may be integrative "in identity" but modern "in practice," and both can be true. Lastly, the IWF's reliance on self-reports may be vulnerable to identity-related bias. As Brenner and DeLamater (2016) argue, respondents often answer survey questions in ways that reflect their "ideal" self rather than their "enacted" self. This process, sometimes mistaken for social desirability bias, suggests that students may select options that reflect who they aspire to be or believe they should be, rather than how they consistently reason. In this case, Della's integrative classification may capture an aspirational view of herself, while her written responses provide a clearer window into her enacted reasoning.

Explorers further demonstrate fluidity in expression, as illustrated by the case of Pippa. Over the course of the semester, Pippa engaged with three writing prompts, all focused on invasive species, but responded from three entirely different worldview orientations (Figure 2.5). Even though the content focus remained constant, her reasoning shifted from a traditional emphasis on restoring ecological balance, to an integrative stance grounded in intrinsic value, to a modern framing that highlighted ecosystem services. One explanation for this pattern is that students may be undergoing active worldview development, transition, or transformation. Prior research has shown that emerging adulthood is a period of considerable worldview change, with

college students frequently reexamining inherited belief systems and integrating new perspectives introduced through coursework and life experiences (Gutierrez & Park, 2015). Bruner and colleagues (2014) similarly argue that university students are situated within a broader cultural shift, often moving away from modern worldviews and toward postmodern or hybrid perspectives. While we did not observe clear cases of this transition, the variability expressed by Explorers may reflect students during a transition, with their written arguments capturing moments of negotiation. Another explanation is that these shifts may reflect the student's responsiveness to how each prompt was framed, whether it asked them to imagine themselves as a city planner, to engage in moral reflection, or to assess ecological disruption from the perspective of a federal employee. This case illustrates that students' written arguments may not always directly reflect their internal belief systems but instead emerge as dynamic responses shaped by the prompt and the roles they are asked to portray. Future studies that include follow-up interviews or think-aloud protocols could provide deeper insight into how students interpret the prompts and reason through their arguments.

The role of classroom norms and expectations

Interview data added important context to the patterns observed in students' writing. Although the interviews were conducted at the beginning of the semester, before students had completed many assignments, they still revealed insights into students' broader experiences in academic settings. Several students explained that they often shaped their writing to appeal to what they believed their instructor wanted to hear, drawing on prior experiences in other courses where grades were tied to sounding "scientific." This tendency appeared to persist even in the current course, despite homework prompts explicitly encouraging students to draw on their own beliefs, experiences, and values, and awarding full credit regardless of the position they took.

The interviews suggest that students may carry implicit expectations into writing tasks, such as when it comes to expressing values or epistemologies that diverge from dominant norms in science classrooms or when balancing learning and performing. Prior research on writing tasks reinforces this point, showing that writers adapt their style, reasoning, and use of evidence depending on the specified audience or perceived expectations (Chesky & Hiebert, 1987; Cho & Choi, 2018; Midgette et al., 2008). Similarly, Perry (2011) found that students' beliefs about writing ability influence whether they approach writing as a task for performance or learning. Those focused on performance tend to conform to what they think instructors expect while those focused on learning are more likely to take risks and reflect on their ideas. This helps explain why worldview expression in writing may reflect both students' own beliefs and what they have found to work in previous classroom experiences.

A recurring theme in student interviews was the experience of knowledge dissonance within their coursework. Students, like Thea and Kiki, shared that they felt a tension between their own worldviews and knowledge and the perspectives emphasized in their past classes. Students described where their personal understandings of environmental issues, shaped by cultural backgrounds, life experiences, or ethical beliefs, did not align with the scientific or technical approaches taught in former classes. Even when they respected academic knowledge, students sometimes felt there was little room to question, discuss, or work through these differences. As a result, some students admitted to completing assignments for prior classes by drawing on academic sources, such as content covered in lecture, even when they personally disagreed or did not feel aligned with the ideas they were recommending. These moments of dissonance point to a gap in how ecology education often engages with the complexity of students' lived experiences and values. Creating opportunities and time for students to explore

these tensions in the classroom could help deepen their critical thinking and strengthen connections between different sources of knowledge. Instructors might implement writing-to-learn activities that encourage students to integrate scientific, personal, and cultural forms of knowledge. For instance, the Cognitive-Affective-Behavioral WTL model (Balgopal and Wallace, 2013) guides students through expository, narrative, and persuasive essays about SSIs, helping them to connect what they know, feel, and would do. Similarly, reflective writing assignments can help students engage in an internal dialogue that bridges their worldviews with other forms of knowledge (Balgopal & Montplaisir, 2011).

The role of SSIs in supporting integrated social-ecological reasoning

The findings of this study also signify the potential of environmental SSIs as a powerful tool in ecology classrooms. By design, SSI tasks invite students to consider scientific principles in relation to personal experiences and social contexts. In doing so, they provide opportunities for students to identify and practice their own ways of integrating their worldviews, prior knowledge, and new academic knowledge learned in class. The work of Klaver and colleagues (2023) has shown that students rely on a diversity of resources (e.g., scientific knowledge, cultural values, lived experience) when reasoning about complex issues. SSI-based assignments highlight these intersections, making visible both the stability of worldviews (as with Anchors) and the negotiation and compartmentalization strategies seen in Adapters and Explorers.

For many students in this study, writing about wolves, invasive species, or bird feeders prompted them to draw not only on ecological concepts, but also on religious faith, spirituality, cultural traditions, or personal observations. These responses demonstrate that SSIs can help students to reason through multiple knowledge systems they bring into the classroom, even when those systems conflict with the norms of science curricula. Importantly, SSIs also create a space

where such tensions can be productively examined. As the experiences of Thea and Kiki illustrate, some students feel compelled to silence or compartmentalize aspects of their worldview in science classrooms. Embedding SSIs can counter this tendency by legitimizing diverse perspectives and encouraging students to explore how their personal, cultural, and scientific understandings relate to one another (Balgopal et al., 2017; Högström et al., 2024).

Limitations

Many of the explanations we have highlighted for the potential mismatch between classified and expressed worldviews were also limitations of our study. For instance, relying on the IWF survey as the sole instrument for classification constrained how precisely we could capture students' worldview orientations. The survey sought to categorize students through closed-response items covering different worldview dimensions (Table 2.1). In authentic contexts, as we simulated in our homework prompts, this may not align clearly with students reasoning. The timing, scope, and quantity of interviews presented another limitation. Our interviews were conducted at the start of the semester and with a small sample of students. Although they provided nuanced understanding of how and why students expressed particular worldviews in their writing, they provided little information about how their worldviews might shift as they continually engage with SSI prompts over the semester. A longitudinal design or interviews conducted after the students had completed the course could have revealed a clearer relationship between their survey classifications and expressed reasoning.

Another limitation not yet discussed was the asymmetric representation of framings (personal versus professional) and themes (species introduction, invasive species, pathogen spread, habitat fragmentation, and environmental management philosophical dilemmas) within our prompts. In the first year, five prompts were administered, four of which asked students to

respond from a professional role rather than a personal perspective. Across both years, questions related to species introduction or invasion were disproportionately represented, while other themes received less attention. Moreover, one theme (fragmentation) did not include any prompts written from a personal framing. This imbalance is significant because the framing and content of a prompt can influence how students position themselves and the kinds of reasoning they use in their writing. Overrepresentation of certain framings or themes may therefore have constrained the variety of worldview expressions observed, while the absence of personal framings for some themes may have limited opportunities for students to explicitly connect their worldviews and lived experiences to ecological content.

Another limitation was that only 10% or fewer of each class enrollment was interviewed, and because students volunteered, those who were already interested in discussing worldviews may be overrepresented in this sample. Because students had only completed one or two SSI homework assignments by the time they were interviewed, we cannot claim with certainty that their experiences in past courses were reflected in this one. Finally, we did not interview students by the end of the course to determine if the mid-week small group discussion time was used by students to reconcile different funds of knowledge. Students were not told how to use their time in small groups but were encouraged to review homework prompts and determine how best they could use the time with their peers.

Finally, we did not collect additional data as participant observers of the course, so we did not collect data on the types of questions that students asked or the subsequent discussions that arose in class outside of the small group work mid-week. This would have allowed us to better capture how the instructor presented his worldview to students. While the instructor's

worldview was classified as postmodern through the survey, it is possible that his classroom discourse did not exactly align.

Implications and future research

Our findings suggest that many undergraduate students are still in the process of forming or negotiating their worldviews, and that the classroom culture itself can shape how and whether those worldviews are expressed in written work. If students are actively weighing their values, roles, and criteria for "what counts" in homework assessments, then educators should design structured, low-stakes assignments that help them reason through this explicitly. For example, assignments that invite students to compare reasoning from multiple worldview perspectives, or to reflect on how their worldviews align or diverge from disciplinary norms, could help them practice integrating diverse forms of knowledge. Classroom climate and instructor modelling are equally important. When instructors acknowledge that worldviews may inevitably shape ecological decision-making, they signal to students that integrating their lived experiences with academic reasoning is a part of becoming an effective practitioner. Intentional opportunities for students to explore how their worldviews intersect with ecological content may therefore serve as a simple, scalable way to help them connect who they are, what they are learning, and who they are becoming in ecological-adjacent careers.

The patterns of Anchors, Adapters, and Explorers identified in this study also highlight directions for future research. First, the reliance on surveys and written homework alone limited our ability to fully capture how students interpreted prompts or navigated tensions in real time. Future studies should incorporate longitudinal interviews to better understand how student employ or draw on their worldviews across contexts, courses, and time. Second, more balanced designs are needed to examine the effects of prompt framing and theme representation. Ensuring

symmetry between personal and professional framings, as well as a wider distribution of ecological themes, could reveal whether observed variability reflects effects of prompt design or deeper worldview dynamics. Third, expanding this work across multiple institutions and disciplines would help determine the generalizability of these patterns and how classroom cultures shape worldview expression. Finally, research should continue to examine how classroom practices, such as modelling by instructors, influence whether students compartmentalize, adapt, or integrate their worldviews into learning.

TABLES

Table 2.1 Four common worldview dimensions are used to characterize patterns of meaning-making in environmental decision-making. Descriptions synthesize language across sources; labels sometimes vary, and dimensions may overlap.

Dimension	Description	Source
Ontology	What exists and what is the nature of reality	(Bruner et al., 2014; Cobern, 1996; Cruz et al., 2022; Gutierrez & Park, 2015; Hedlund-de Witt, 2012; Jurin & Hutchinson, 2005)
Epistemology and knowledge	How we know what we know, including what counts as valid knowledge	(Bruner et al., 2014; Cobern, 1996; Cruz et al., 2022; Hedlund-de Witt, 2012; Jurin & Hutchinson, 2005; Lynam, 2019)
Ethics and values	What is good, desirable, or just at a personal and collective level	(Bruner et al., 2014; Cruz et al., 2022; Gutierrez & Park, 2015; Hedlund-de Witt, 2012; Jurin & Hutchinson, 2005; Lynam, 2019)
Beliefs about human nature	Assumptions about what it means to be human, including purpose and growth	(Bruner et al., 2014; Cobern, 1996; Gutierrez & Park, 2015; Hedlund-de Witt, 2012; Jurin & Hutchinson, 2005; Lynam, 2019)

Table 2.2 Alignment categories between classified and expressed worldviews. Each student was classified into one of five worldview clusters (traditional, modern, postmodern, integrative, or mixed) based on the IWF survey (de Witt et al., 2016), and their expressed worldviews were then examined across multiple homework responses. Three categories of alignment emerged: anchors, who consistently expressed the worldview in which they were classified; adapters, who consistently expressed a different but consistent worldview; and explorers, who expressed multiple worldviews across responses. See Appendix 2.4 for complete codebook.

Category	Definition	Characteristics
Anchors	Students who consistently express the same worldview as the one in which they were classified.	Maintains alignment between classified and expressed worldviews across majority of homework responses (e.g., classified as traditional and writes from traditional).
Adapters	Students who consistently express a worldview different from their classified one.	Demonstrates stability in an alternative worldview across homework responses (e.g., classified as traditional but writes from a modern worldview).
Explorers	Students who draw from multiple worldviews across their homework responses.	Demonstrates variability in reasoning, expressing different worldviews across homework responses (e.g., classified as traditional, but writes from modern, postmodern, and integrative worldviews).

FIGURES

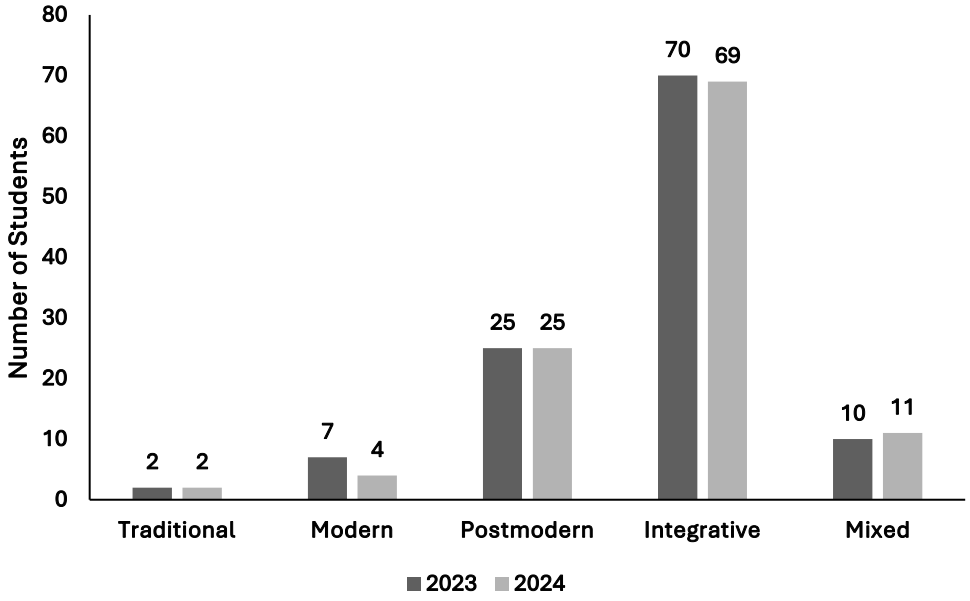

Figure 2.1 Undergraduate ecology students' classified worldviews after completing the Integrative Worldview Survey (IWF); (de Witt et al., 2016).

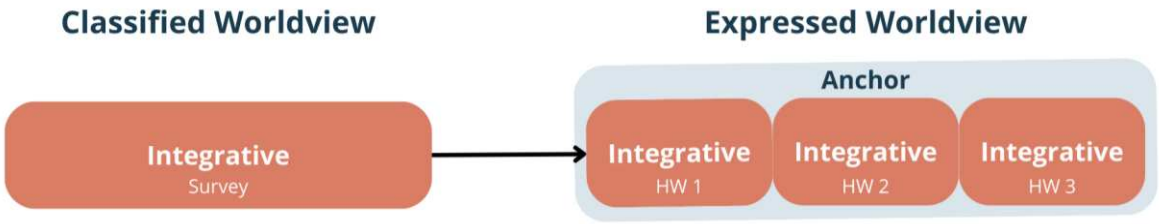

Figure 2.2 Anchor pattern, in which the student's classified worldview (integrative) aligns with the expressed worldview (integrative) across multiple writing assignments.

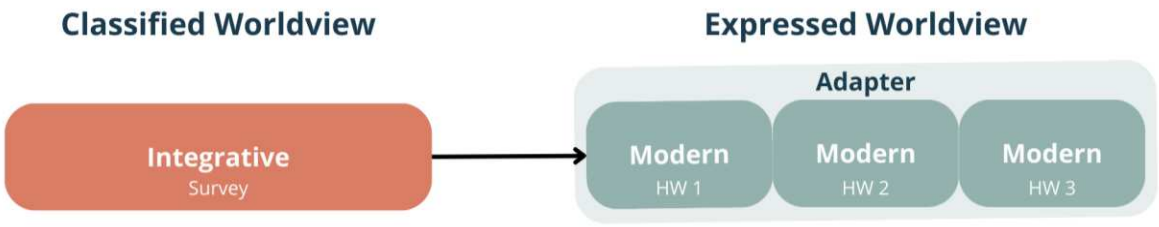

Figure 2.3 Adapter pattern, in which the student's classified worldview (integrative) differs from their expressed worldview (modern) across multiple writing assignments.

Figure 2.4 Adapter pattern, in which the student's classified worldview (traditional) is consistent with their expressed worldview in an interview (traditional) but differs from their homework responses, where they consistently expressed a different worldview (modern) until given the option to explicitly select a worldview aligned response (traditional).

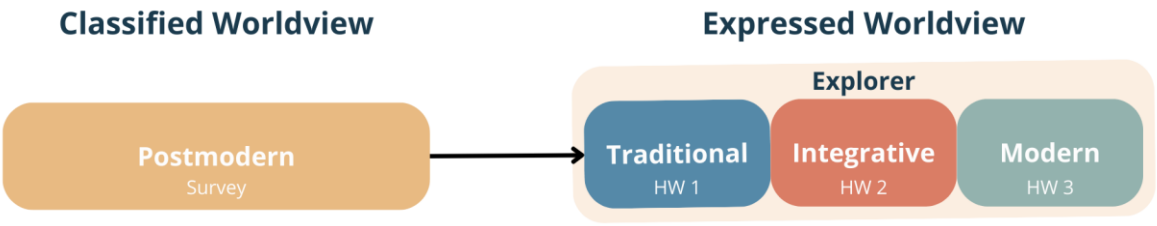

Figure 2.5 Explorer pattern, in which the student's classified worldview (postmodern) differs from their expressed worldviews (traditional, integrative, modern) across multiple writing assignments.

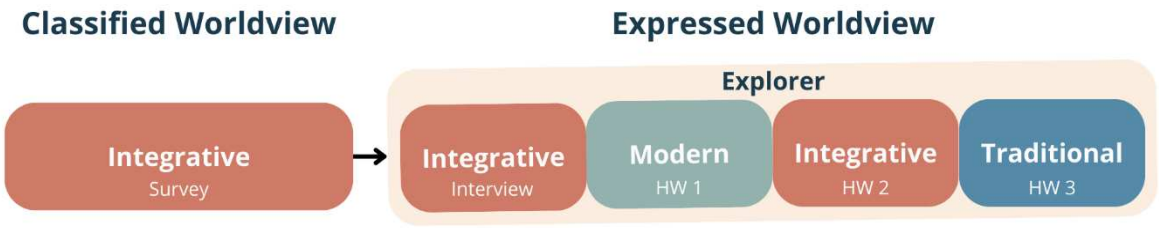

Figure 2.6 Explorer pattern, in which the student's classified worldview (integrative) is consistent with their expressed worldview in an interview (integrative) but differs from their expressed worldviews (modern, integrative, traditional) across multiple writing assignments.

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CHAPTER 3

INTRODUCTION

Socioscientific issues (SSIs) are real-world problems that are both scientifically complex and socially embedded (Sadler, 2011). These issues, such as climate change and genetic engineering, require students to evaluate evidence, consider ethical and cultural perspectives, and engage in informed decision-making (Sadler, 2004; Sadler & Zeidler, 2005). By integrating science with sociopolitical contexts, SSI-based instruction moves beyond rote memorization and helps students develop skills in critical thinking and argumentation (Sadler et al., 2007). Within ecology education, SSIs provide rich opportunities for students to connect core disciplinary concepts (e.g., biodiversity, population dynamics, and ecosystem resilience) to pressing environmental challenges (Kinslow et al., 2019; Kumar et al., 2024). Issues like invasive species or habitat restoration allow students to see how science informs decision-making in real-world contexts, bridging the gap between theoretical content and societal relevance. Through these experiences, students come to view science as a dynamic and socially engaged practice rather than a static body of facts.

The implementation of SSIs in undergraduate ecology education advances the goals of ecological and scientific literacy by fostering students' understanding of the nature of science, critical evaluation of evidence, and the application of knowledge to societal challenges (Klemow et al., 2019; Rodgers et al., 2024; Zeidler, 2014). When designed well, SSI-based learning promotes both content mastery and higher-order thinking, preparing students to navigate the complex and value-laden scientific issues they will encounter as professionals and citizens

(Dauer et al., 2021). This potential, however, is actualized only when educators have the tools and strategies to integrate SSIs into the curriculum meaningfully.

Challenges in Teaching SSIs

Despite widespread agreement on the value of SSI-based instruction, educators face significant challenges when incorporating SSIs into their teaching. Studies consistently show that teachers often feel ill-prepared to address the complex and interdisciplinary nature of SSIs (Relela & Mavuru, 2023; Zhang & Hsu, 2025). For example, teachers frequently report feeling uncomfortable facilitating open-ended discussions that could challenge students' religious or cultural views (Levinson et al., 2001). In the context of life sciences, topics like evolution or environmental protection often provoke tensions, leaving educators uncertain about how to foster inclusive yet rigorous discourse (Berkman & Plutzer, 2011; Pobiner, 2016). This lack of confidence can result in superficial coverage of SSIs, limiting students' opportunities to engage in the type of critical reasoning and dialogue these issues demand. Furthermore, research on science communication has demonstrated that presenting factual evidence in ways that conflict with students' prior beliefs can sometimes trigger biased assimilation, or the "backfire effect," where learners strengthen their existing views rather than reconsider them (Sauer et al., 2021). Thus, instruction needs to be both attentive to content knowledge and the social factors that shape how students interpret controversial science.

Pedagogical constraints further compound these challenges. Many instructors lack the targeted pedagogical content knowledge needed to effectively integrate SSI-based instruction into their classrooms (Kinskey & Zeidler, 2024). Without training in how to scaffold argumentation or address conflicting perspectives, they may avoid SSIs altogether. In undergraduate settings, systemic barriers such as content-heavy curricula, large class sizes,

limited instructional time, and pressure to prioritize disciplinary "coverage" over discussion of societal relevance can likewise dissuade educators from implementing SSI-based teaching (Zhang & Hsu, 2025). As a result, even when SSIs are included, the instruction often defaults to a narrow focus on factual content, failing to engage the broader societal and ethical dimensions that make these issues valuable for student learning.

These challenges highlight the need for research that provides educators with insight into how students approach SSIs. By understanding the types of knowledge and resources students draw on when reasoning about these issues, teachers can better design instruction that resonates with students' perspectives and helps them critically evaluate evidence. Investigating students' "resource repertoires" is particularly important in higher education, where students' disciplinary training, cultural backgrounds, and personal experiences vary widely (Cuyjet et al., 2023). A more detailed understanding of these resources can inform both curriculum design and professional development for educators who wish to foster meaningful SSI discussions.

Student Knowledge and Resources in SSI Engagement

Students do not approach SSIs as blank slates (Bossér & Lindahl, 2019). Instead, they rely on a blend of resources that includes formal academic knowledge, personal and family experiences, cultural traditions, information from media or community contexts, and broader norms and discourses in society (Evagorou et al., 2012). For example, when evaluating a local environmental issue, a student might draw on scientific concepts learned in class, combine them with personal observations of ecological changes, and incorporate perspectives shared by family

members or community leaders. These varied resources shape how students frame problems, what solutions they find plausible, and how they justify their claims (Jimenez et al., 2024).

Understanding the resources that students draw upon is crucial because students' reasoning may be a reflection of their worldviews, or their structured systems of meaning-making (Hedlund-de Witt, 2014). Students may prioritize certain forms of knowledge, such as lived experience or community values, over scientific evidence, particularly when they perceive a mismatch between classroom instruction and their personal views (Sauer et al., 2021). By recognizing the range of resources students employ, educators can design SSI-based learning experiences that build on these strengths while encouraging critical examination of diverse information sources.

Frameworks that explore students' resources

Previous studies have outlined various frameworks for characterizing what resources students draw on when reasoning about SSIs (Otto et al., unpublished; Zeidler & Sadler, 2023; Table 3.1). In these frameworks, the term "resources" refers to the specific ideas, experiences, and source of information that students actively use when making sense of an issue – such as prior experiences, beliefs, cultural backgrounds, or conversations with peers and family. In contrast, "capital" describes the broader, more stable forms of knowledge, dispositions, and connections that students possess before entering the classroom. In other words, capital represents what students have while resources represent what they use. Here, we briefly justify our choice of Socioscientific Capital for our analysis.

Klaver et al. (2023) introduced the SSC framework to address gaps left by earlier models by characterizing what resources appear in students' arguments and how those resources are activated, combined, and filtered in specific contexts. This new and emerging model expands on

prior frameworks to provide a more holistic account of the resources that students bring to SSIs. In our adaptation (Figure 3.1), SSC is organized into three interrelated categories: meta-level resources (i.e., broad societal influences such as cultural norms and dominant narratives), student SSC at the resource level (i.e., the combination of values, beliefs, and knowledge possessed by the student or others), and student reasoning at the behavioral level.

A strength of the SSC framework is its ability to capture how students draw connections between their internal and external resources and the broader societal structures in which they live. For example, a student discussing invasive species might blend ecological principles learned in class with personal outdoor experiences and observation, advice from an internship mentor who works in forestry, and cultural narratives about environmental stewardship. SSC provides a lens for understanding how students integrate resources, offering a more nuanced view of student reasoning.

Purpose and Research Aims

Despite its conceptual promise, SSC is still in its infancy and remains underexplored in empirical research. It has primarily been used as a conceptual framework in European K–12 settings, often to support teacher professional development or curriculum design (Klaver et al., 2024; Klaver et al., 2023). To date, no studies have operationalized SSC as a coding scheme for systematically analyzing student reasoning, nor has it been applied to U.S. higher education contexts such as undergraduate ecology courses.

This study responds to these gaps by applying and extending the SSC framework in an undergraduate ecology course. It explores how students make sense of environmental SSIs and analyzes the resources that students draw upon in their written responses.

METHODS

In this study, we employed a mixed-methods design (Creswell & Creswell, 2017) to investigate the SSC students drew upon when reasoning about environmental SSIs. We analyzed two types of data (semi-structured interviews and written assignment responses) to identify the types of claims, the reasoning strategies, and supportive evidence students used. This study was approved by Colorado State University's Institutional Review Board (Protocol #3475).

Study Context

The research took place in a large-enrolment, upper-division undergraduate ecology course across two consecutive years (spring 2023 and spring 2024) at a land-grant university in the Mountain West region of the United States. The course introduced students to ecological principles, emphasizing the relationships between organisms and their environments across scales, from individuals to ecosystems. Topics included biodiversity, population growth, and species interactions, with supplemental environmental science examples (e.g., climate change, habitat fragmentation, and the design of nature reserves). While multiple instructors at the university teach the course, all data for this study were collected from sections taught by the same instructor, ensuring consistency in content and teaching. The instructor, a community ecologist with 35 years of research experience, had taught ecology courses for 23 years. The course is required for several majors, both foundational (e.g., biological science, zoology) and applied (e.g., conservation biology). Although the course followed a tightly prescribed curriculum, it incorporated multiple forms of active learning, including weekly guided analysis of primary scientific literature (PSL) related to the course topics. As is typical of life sciences at this institution, women comprised 69% of the course population. The student demographics mirrored those of the university, with 69% identifying as white, 15% as Hispanic/Latinx, and 5% as multiracial.

Data Collection and Analysis

Written Assignments

Throughout the semester, students completed a series of written assignments designed to elicit their reasoning about environmental SSIs (see Appendix 2.3 for prompts). These assignments were aligned with the PSL for a given week. Over both semesters, students responded to prompts across four assignments. Each prompt asked students to adopt either a personal perspective (drawing on their own values or beliefs) or a professional perspective (responding as an ecologist, city planner, or local volunteer). Prompts were grouped around four themes: species introduction, invasive species, pathogen spread, and habitat fragmentation. All students responded to the same prompts.

Students' written responses were analyzed deductively using a structured coding scheme (Table 3.2) informed by the SSC framework (Klaver et al., 2023). Although SSC is a relatively new conceptual model rather than a formal codebook, it provides a theoretical foundation for identifying internal, external, and meta-level resources. Codes were applied when the response contained explicit to reasonably inferable evidence of a given resource type as outlined in the codebook. For example, Internal-Experience was applied when students referenced personal or lived experiences, such as describing their own participation in hunting or making observations during fieldwork or employment. Codes were applied in combination when multiple resource types were evident within a single resource – for instance, when students drew on External-Media sources to support their Internal-Values or Internal-Beliefs about a particular topic. Co-occurrence of codes also occurred when a single reference represented multiple resource types, such as undergraduate research experiences that reflected Internal-Experience, External-Academic, and Internal Skills.

Two researchers independently coded an initial subset of responses to refine the codebook and ensure consistency. After resolving discrepancies through discussion, one researcher coded the full dataset. We then examined resource use patterns across responses, focusing on how students drew on different forms of SSC in reasoning about environmental SSIs.

Trustworthiness

We used multiple strategies to establish trustworthiness. In addition to our primary data set (i.e., written assignments), we also conducted semi-structured interviews to support triangulation of our data. Interviews (n=24, 11%), conducted by the first author during the first three weeks of the semester, explored students' perceptions of nature, human–environment relationships, and the kinds of knowledge they typically drew upon in academic work (see Appendix 2.2 for interview protocol). Interviews were recorded and transcribed using OtterAI, and the transcripts were reviewed and verified before analysis. Although not a primary data source, these interviews informed the development of the coding framework and interpretation of students' written assignments by illustrating how they described their use of resources in reasoning. Transcripts were analyzed thematically (Braun & Clarke, 2006) to identify patterns consistent with codes from students' written responses and were discussed through peer debriefing to reduce bias.

RESULTS

A total of 225 students (spring 2023: 114; spring 2024: 111) participated in this study, each responding to four homework prompts designed to explore their reasoning and decision-making on environmental SSIs. Students drew upon a broad range of SSC across internal, external, and meta-level resources, with notable variation between personal and professional

perspectives (Figure 3.2). Internal resources dominated overall, accounting for roughly two-thirds of all coded instances across prompts. Students' knowledge was most frequently referenced (214-224 instance per prompt), followed by skills (62-128 instances per prompt). When writing from a personal perspective (HW2), however, students drew on a broader mix of affective and identity-centered resources, particularly values (n=89), beliefs (n=124), and attitudes (n=94), which collectively tripled their prevalence compared to the professional-perspective prompts. External resources contributed a smaller but still substantial proportion of total codes (between 15-25%), led by academic knowledge (98-170 instances per prompt). Notably, references to community knowledge increased markedly in the personal-perspective prompt (n=51) compared to the others (n=0-19). Finally, meta-level resources were well represented across the dataset. Dominant discourses were consistently high (between 62-154 instances per prompt), while cultural norms peaked in the personal prompt (n=70). The following sections further explore how students used the SSC resources in their writing.

External SSC

Media

Media capital was evident when students incorporated ideas, facts, or examples from news outlets, online articles, social media platforms, or other publicly accessible media sources. These references frequently appeared when students were tasked with generating novel solutions or expanding scenarios beyond the materials provided in class.

One context where media was prominent was in response to a prompt asking students to propose solutions for managing emerald ash borer (EAB) populations. Several students turned to online sources to identify potential interventions. For example, one (RESP_001-SP23) cited a New York Times (NYT) article when writing, "*There are scientists that have been spraying the*

ash trees with a plant hormone…when the hormone is released the plant starts to make inducible compounds which then kill the EAB." By citing a newspaper article and describing the mechanism in detail, the student demonstrated how media can serve as an accessible tool for integrating research and applied management. A different student (RESP_005) responding to the same EAB prompt explained, "*Another possible solution to stop EAB spread would be to move away from wood packaging and logging… eliminating the movement of trees would stop the assisted dispersal of these insects… This idea was from more online research."* Here, the student indicated their use of media as a resource and a space for inquiry, using online materials to broaden the scope of their management strategies.

Media sources also emerged in response to a prompt asking students to propose a water management plan for a large, western, and water-scarce U.S. city. One student (RESP_028) built their proposal around conservation strategies described in two online publications from the National Geographic Society (Nat Geo) and the World Wildlife Fund (WWF), noting:

> *Within any community, implementing smart water usage techniques will be a great way of increasing water efficiency and reducing waste…* [One] *way to promote this change would be to create an incentive for the public... Restoration efforts would also… help not only wildlife but would* [create] *more recreational opportunities for people in the community.*

This student used media evidence to anchor their strategy in recognizable and reputable sources to bolster the legitimacy and practicality of their solutions.

Not all media sources reflected established journalism; some drew from informal or emergent platforms like social media. In another water management response, a student (RESP_079) wrote, "*The use of green infrastructure such as bio swales, rain gardens, and green roofs can help manage stormwater runoff… I learned a lot about green infrastructure through TikTok*." This case illustrates how informal science communication channels can shape students'

awareness of ecological solutions. Examples like these demonstrate the range of media sources students view as credible or influential, ranging mainstream organizations like NYT and Nat Geo to social media platforms, like TikTok.

Community

Community capital appeared when students drew on perspectives, practices, or values from groups or organizations beyond their immediate family or formal academic contexts, such as local conservation networks and rightsholder or stakeholder communities. In a homework prompt on wolf reintroduction to Colorado, a recently approved proposition on the state ballot, students were asked to evaluate the ecological, social, and economic implications of this conservation initiative.

Some students emphasized cultural traditions as a source of community capital, situating wolf reintroduction within Indigenous livelihoods. One student (RESP_010) explained, "*While the reintroduction and management of the wolves will have to be closely monitored and mandated, it is essential that we work on recovering this species before it is too late."* Here, the student frames wolf reintroduction as an urgent conservation responsibility, acknowledging that recovery requires structured management. The student continued, "[I] *believe that the wolves need to be reintroduced so they can keep their ties with, not only the land, but the natives who value them in their culture."* By framing reintroduction as essential to maintaining the relationship between wolves, land, and Native communities, the student draws directly on community capital. Their reasoning reflects the idea that ecological outcomes are inseparable from cultural survival and the values held by rightsholders groups. They elaborated, "*The Ojibwe tribe is specifically tied with wolf species due to their importance in creation stories and how they are considered as family members to the tribe."* By highlighting creation stories and kinship

ties, the student situates wolves as more than just part of a food web but as relatives within Ojibwe traditions. Finally, the student concluded, "*By letting the wolves die out… we are… ripping away parts of the Native American culture for unnecessary reasons*." Here, community capital is expressed strongly: ecological loss is equated with cultural erasure. This reasoning illustrates how students can leverage community knowledge to frame biodiversity conservation as inseparable from the preservation of Indigenous heritage.

Other students drew on conversations with peers and awareness of broader stakeholder communities. One (RESP_101) reflected:

> *This is something I have thought about for a while actually… I have lots of friends in the conservation field and have spoken with them on this topic as well… I believe passing a bill with the intent of reducing the wolf population…is a byproduct of poor planning or forethought. Human (livestock) and predator interaction will always be an issue and states that have had wolves for a while are already working means of coexisting which seems to have made a difference in livestock predation at some cost.*

This example shows how informal professional networks can shape students' reasoning by exposing them to varied perspectives from practitioners. Similarly, another student (RESP_014) drew on their empathy for local stakeholders, writing:

> *Ranchers don't want their livestock to be under threat when currently the threat is low, and it would hurt them financially as they can't sell cows that got snatched…I have sympathy for the troubles that ranchers, and their livestock, would experience.*

This student continued to evaluate "*both sides of the argument*" by integrating local knowledge of the state, sharing how Colorado has a history of economic and ecological destruction from flooding. They proposed that reintroduction may be a mechanism to stabilize the river banks and subsequently reduce damage caused by flooding, indicating that these benefits outweigh the concerns from the local ranchers. This process of weighing multiple community narratives was common for this homework prompt and shows how students actively consider trade-offs when making decisions.

Family

Family capital often emerged when students described how their views or knowledge on social ecological issues were shaped by household practices, often from childhood, or advice from their relatives. This external resource was most evident in homework prompt three, which positioned students as volunteers for a nature association and asked them to consider the trade-offs between aesthetic enjoyment and ecological health when using bird feeders.

Some students expressed surprise at reconsidering long-held assumptions that originated from family norms. For example, one student (RESP_081) reflected, "*My mom loved to put out bird feeders in the backyard when I was a child, so I had never really considered their environmental impact until now.*" Here, the student situates their baseline perception of bird feeders within a positive childhood memory, acknowledging that this familial practice shaped their initial understanding. They then expand on their current perspective by incorporating knowledge gained from coursework, noting that, "… [birdfeeders have the risk of] *increasing disease transmission, increasing predation risks, and potentially attracting invasive or unwanted species*." This shift illustrates how course materials prompted a reassessment of a previously unrequested practice.

Other students described adopting practices or viewpoints directly from family members. One (RESP_109) noted, "*From growing up, my parents never wanted to have bird feeders because they could invite more birds to pick at our garden and trees they didn't want.*" This example illustrates how family attitudes toward wildlife management, in this case, preventing nuisance behavior, can influence students' own evaluations of environmental practices, even in contexts beyond the original concern. In both examples, family influence served as a starting point for students' ecological reasoning and a comparative lens through which they assessed new

information.

Academic

Academic capital was the most common external resource students drew upon when reasoning about social ecological issues (Table 3.2). This included ideas from coursework and lectures, information from outreach materials (i.e., non-course academic materials) such as extension websites (co-coded with *Media)*, and knowledge gained through undergraduate research experiences (co-coded with *Experience)*. For instance, when asked how to manage the EAB population in North America, many students referenced content from lectures and other current or former coursework. One student (RESP_038-SP23) suggested limiting the transportation of ash tree firewood to prevent the spread of the invasive insect, explaining, "*…you can push to stop transportation of ash trees so that the EAB are no longer being transported and spread. In my knowledge from* [evolution]*, insects with a set preference of food rarely deviate from their diet."* Here, the student applied an idea learned in their undergraduate evolution course, that insects with fixed dietary preferences rarely deviate from their food source, to propose a practical management solution.

Students also used information from public outreach materials to inform their decisions. One student (RESP_038-SP24), for example, summarized recommendations from their university's Extension office, noting four different types of insecticide application methods (soil drenches, trunk injections, trunk sprays, and foliar sprays) are available to manage EAB infestations. Rather than drawing from lecture content, students referenced other academic resources to support their proposed solutions.

In a few cases, students connected their academic research experiences to their reasoning. One student (RESP_007), for instance, drew from their undergraduate research, writing,

"*Another possibility would be to spray ash trees across the nation with some kind of pesticide specific for the EAB... My undergrad thesis is about GMOs and their role with pesticides and there are many caveats to [pesticide use].”* Here, the student acknowledged limitations of their proposed solution, indicating how their research experience has shaped their technical knowledge and ability to weigh trade-offs.

Internal SSC

Knowledge

Knowledge capital was the most prevalent internal resource, with students applying scientific concepts and contextual knowledge to justify their reasoning. In the bird feeder prompt, some students drew on disease ecology, predatory-prey dynamics, and competition without citing where these ideas originated, presenting them as established knowledge. One (RESP_031) explained that feeders:

> *can also cause birds to become reliant on humans for food or other resources, and cause transmission of diseases… We know that different species can compete for resources such as food, which can push out certain species if they are not able to aptly compete*.

Another (RESP_055) noted, "*Bird feeders can attract unwanted wildlife to areas — such as bird feeders bringing bears into urban settings. Lastly, creating a known food source for these birds can also bring more of their predators to the area, which could hurt their populations*." In both cases, students applied core ecological principles as part of their reasoning, without identifying a specific source.

In other cases, students integrated detailed, specific information that likely originated from an external source, but presented it as part of their personal knowledge base. This was particularly evident in the EAB management prompt. One student (RESP_086-SP24) wrote*:*

> *Introducing more biological control agents, such as Tetrastichus planipennisi, may help… In Europe, this was effective when parasitic wasps were used to control the*

> *number of cabbage white butterflies… Another option is installing monitoring systems… as we attempt to control the Asian giant hornet invasion we are currently experiencing.*

The comparison to other invasive species management efforts suggests prior exposure to course content or media, but here they are embedded in the student's own reasoning. Similarly, another student (RESP_071) proposed:

> *One solution… is putting restrictions on wood cutting/transporting in all areas where EABs are known to inhabit…* [Another solution] *is getting rid of the ash tree populations that they inhabit… The bugs get around the fastest with the help from people, so preventing that would slow the spread.*

While transport restriction is a recognized invasive species management strategy, the student presents it as commonsense knowledge integrated into their own evaluative framework.

Experience

Experience capital was coded when students drew on personal observations, prior volunteer or internship work, or professional employment to inform their reasoning. These references often grounded ecological concepts in tangible, real-world encounters, allowing students to position themselves as knowledgeable contributors through first-hand engagement with the issue.

In the water scarcity prompt, some students framed their decisions through the lens of their own professional work. One student (RESP_054) explained:

> *I work in landscaping for most of the year and one of the most expensive parts for homeowners is water usage to keep plants alive…the vast majority of people would rather spend copious amounts of money on their water bill than consider transitioning their property to mulch/gravel with succulents… This means that the only real way… is to ban unnecessary uses of water.*

Here, the student's job provided both observational evidence about public behavior and insight into the limitations of policy tools like water pricing. Similarly, another student (RESP_105) drew on their professional experience, proposing, "*The use of water-sensitive urban*

design (WSUD) incorporates natural hydrological cycles into city planning… This is learned field work from an environmental engineering company I work for." In both cases, students used their professional experiences to validate the relevance and feasibility of their recommendations.

Travel and place-based exposure also served as sources of experiential knowledge, such as observations connected to pest management. One student (RESP_065) recalled:

> *'trap trees' can also be used to slow the spread of the EAB, cutting a gap in the bark of some ash trees will attract the beetles and can then be cut down and destroyed before the larvae can hatch, I've seen these trees like this while traveling through Minnesota*.

Another (RESP_020) wrote, "*Controlled burns… I've seen this through my experience living in Colorado as we've done controlled burns multiple times for invasive species and debris control*." These observations from lived environments provided concrete examples that students could draw upon to illustrate management practices already in use elsewhere.

Attitude, Values, and Beliefs

Students expressed deeply held values about environmental stewardship, fairness, and human-nature relationships. Attitudes appeared when students signalled positive or negative evaluations of management actions, while beliefs were articulated as normative statements about how people or systems should function. These three internal resources were drawn on most in the wolf reintroduction prompt.

Some students supported reintroduction on ecological and moral grounds, while also addressing shifts in societal perception. One student (RESP_086-SP23) explained:

> *My personal position is that of support to reintroduce wolves… Wolves are very important for keeping the number of herbivores* [in check]… *There used to be a stigma about them a long time ago, that they were very dangerous… if we leave them alone, chances are they will leave us alone…I would really like to see them return just because I think it's the right thing to do.*

Here, the student's positive attitude toward wolves is coupled with an ecological belief in

their role as keystone species and a moral value expressed in the "*right thing to do*" framing. This example shows how students' intrinsic motivations can shape their understanding and reasoning of human-wildlife coexistence.

Other students expressed cautious support rooted in their personal and professional identities. One student (RESP_001-SP24), who made explicit their identity as a student in agriculture, said:

> *While I value the diversity and beauty that comes with the wolves, as an agriculturally based individual, I find it hard to justify the benefit of wolf reintroduction… As a person who invests in the wellbeing of their animals, this is cruel… Until a good solution can be found to prevent excessive livestock loss, I don't know the correct answer… but hope they can find a way to make it work.*

This response reveals a strong value for animal welfare in livestock care, a belief that current protections disadvantage ranchers, and a cautiously negative attitude toward reintroduction under existing conditions. However, the student's willingness to consider coexistence solutions also shows how values can be dynamic.

Although both students wrote from contrasting support for wolf reintroduction, what is similar is how they leveraged their attitudes, values, and beliefs to reason through this topic. Their responses indicate how deeper held internal resources are as influential in environmental decision-making as ecological data.

Skills

Skills capital was coded when students demonstrated reasoning, argumentation, information evaluation, or decision-making. Although applying these processes was an intended outcome of the homework prompts, and of socioscientific issues (SSIs) more broadly, they were evident in only 55% of total responses. Skills often appeared in close connection with other internal and external resources described earlier, making them best understood by revisiting

select responses from prior sections. For example, in the wolf reintroduction prompt, RESP_101 (see *Community*) integrated perspectives from peers in conservation and compared Colorado's situation to that of other states, highlighting both benefits and costs. Similarly, RESP_014 explicitly considered "both sides of the argument," balancing empathy for ranchers with potential ecological benefits such as riverbank stabilization. In the emerald ash borer (EAB) management prompt, RESP_086-SP24 (see *Knowledge*) compared multiple invasive species control efforts, while RESP_071 connected a specific human action (wood transport) directly to its ecological consequence (spread of EAB). These examples illustrate how students integrate reasoning skills with other capital, demonstrating higher-order thinking that SSIs are designed to promote.

Meta-Level SSC

Dominant Discourse and Cultural Norms

Dominant discourse capital was coded when student reasoning aligned with, critiqued, or reinforced dominant societal narratives, such as conservation versus economic growth or the urgency of climate action. For instance, in the water scarcity prompt, this appeared in several recurring framings. Some students emphasized personal responsibility, stating that, "*If everyone did one small action toward saving the natural areas around us we wouldn't have to worry about losing our environment*" and "*We don't need to take a 45-minute shower when we could be out in 5. We can turn off the water*." Others expressed optimism in technological and infrastructure solutions, consistent with the belief that human innovation can offset environmental limits, as in the claim "*I think that humans need a healthy ecosystem around them to be at their best mentally and physically, and we can use science and technology to bolster natural areas*" and:

> *Documentaries like 'An Inconvenient Truth' and 'Food Inc" have also shown me how without technology, we will never be able to reverse some of the effects of climate change*

and other natural resource issues. Technology will be the most important player in resolving the water problems.

A third set of responses targeted agriculture as the primary source of scarcity, echoing narratives common in policy debates, with one student stating "*I believe a large conflict we run into is water used for agriculture. We need to feed our people, but the amount of water used for agriculture is a huge portion that is removed from natural environments.*"

Like dominant discourse, cultural norms were integrated into students' responses through multiple framings. This resource was coded when student reasoning drew on cultural or national values, identity-based assumptions, or historical framings of issues, and was drawn upon most in the wolf reintroduction prompt. Some students appealed to historical responsibility, stating that "*the wolves shouldn't have been removed in the first place*… [they were] *eradicated solely because they are an inconvenience to humans*," and that "*wolves also deserve to be in their natural habitats, and where they have been and thrived in the past*." Others foregrounded Indigenous cultural heritage, noting that "*wolves have a big spiritual significance among many native tribes, and originally removing them played a part in attempting to erase native culture*." A third set reasoned from place-based identities and state traditions, as in "*as a person who hunts and a Wildlife Biology student… being able to see them in national parks or in the wild would be really cool to me*." As these responses illustrate, meta-level resources shape students SSC. When students draw on these resources in their reasoning, they may reinforce or challenge dominant cultural narratives, ideologies, and values in society.

DISCUSSION

In this study we investigated what socioscientific capital (SSC) undergraduate students drew on when making meaning about environmental SSIs. We operationalized an adaptation of the SSC conceptual model into a codebook and analyzed students' responses to four homework

prompts that varied in perspective (professional versus personal) and theme. Several noteworthy patterns emerged across students' responses.

Dominance of Internal Resources

Internal resources, particularly knowledge, were overwhelmingly prevalent. Nearly all students integrated ecological concepts or context-specific information into their reasoning. However, our data reveal that knowledge was often applied in ways that blurred the boundary between "formal" course content and "commonsense" ecological knowledge (i.e., intuitive or experiential understandings; Kuipers, 1979). Students frequently presented course-based concepts as part of their personal knowledge base, suggesting that academic ideas quickly become embedded in students' internal repertoires. It is also possible that some students supplemented their responses by searching for information without explicit citation, further blurring the line between what knowledge they actually possess and what they retrieve in the moment. This raises important questions for researchers about how to distinguish between knowledge students possess versus knowledge they activate.

Prominence of Academic Knowledge Among External Resources

Among external resources, academic capital dominated. Students frequently drew on lectures, prior coursework, and outreach materials, sometimes supplementing these with experiences from research or professional settings. While this pattern is unsurprising in a university context, it highlights the powerful role of formal academic structures in shaping how students engage with SSIs. By contrast, family, community, and media resources appeared less frequently. When they did appear, however, they added nuance: familial knowledge shaped baseline assumptions (e.g., about bird feeders), media introduced diverse solution strategies (e.g., TikTok references to green infrastructure), and community knowledge provided cultural or

stakeholder perspectives (e.g., wolf reintroduction framed through Indigenous values). These findings suggest that external resources outside the classroom remain an underutilized but potentially powerful dimension of students' socioscientific reasoning.

Role of Meta-Level Resources

Meta-level resources revealed how students' reasoning was embedded in broader societal narratives. Across prompts, students frequently drew on dominant discourses, or the widely shared ways of talking and thinking that circulate through media, politics, and daily conversations. Two recurring narratives were prominent: personal responsibility and technological optimism. Both reflect public framings of environmental sustainability that emphasize personal actions or technological solutions (Nielsen, 2023). For example, students discussed actions such as conserving water or being more mindful consumers, reiterating neoliberal discourses that center responsibility on individuals rather than systemic change.

Differences between personal and professional framings

A noteworthy pattern from our analysis was the difference between students' responses to prompts framed from a personal perspective and those framed from a professional perspective. Although this distinction was not intentional in the original design, it became an important lens for interpreting variation in the types of SSC students used. When students wrote from a professional role, they tended to rely on scientific justifications, patterns consistent with prior working showing that science learners often default to disciplinary norms when addressing SSIs (Takao & Kelly, 2003; Jimenez-Alexandre et al.). In contrast, responses to the personal prompt drew more heavily on affective and moral dimensions, including students' values, beliefs, and attitudes. This distinction parallels what Kahn and Zeidler (2019) described as socioscientific perspective taking (SSPT). SSPT is a process that requires engaging with others' experiences,

shifting between etic (outsider) and emic (insider) viewpoints. The personal framing may have prompted students to express their own values and beliefs alongside ecological concepts, showing how they understood the issues from a scientific and personal lens. In contrast, the professional framing may have encouraged a more detached, technical way of reasoning. In these prompts, students focused on explaining ecological processes and management decisions, which reflected the expectations of scientific writing but left less room for reflection.

Limitations

Several limitations should be considered when interpreting these findings. First, the distinction between personal and professional perspective emerged in our analysis only after data were collected. The homework prompts were not intentionally designed to test differences in perspective, meaning that perspective and theme are confounded. For example, only one prompt explicitly invited students to respond from a personal viewpoint, while the remaining prompts positioned them in professional roles. As a result, the observed variation in SSC may reflect both the type of perspective and the specific issue being discussed, rather than the perspective alone. Furthermore, because the personal perspective prompt occurred only once, we cannot assume that all students would have responded similarly if given more opportunities to write from that perspective. This limitation is particularly noteworthy given that the personal prompt was on a locally relevant SSI that has generated public controversy in recent years, especially in the state where this study was conducted. Such issues often evoke strong emotion and personal reactions because they are relevant to students' experiences and/or to local communities (Herman et al., 2020). The more elaborate use of SSC observed in this prompt may therefore reflect the salience of the local context rather than the perspective itself. Future research could better disentangle these effects by varying both the perspective (personal versus professional) and the context (local

versus global) across multiple prompts. This would help clarify whether affective and value-based reasoning emerges primarily from personal framing, local relevance, or their interaction.

Another limitation is that all data for which we analyzed student reasoning of SSIs came from written assignments. Written responses often reflect the norms of scientific writing, which emphasize objectivity and discourage personal or emotional expression, potentially underrepresenting students' moral or affective reasoning (Balgopal & Montplaisir, 2011; Koster & de Regt, 2020). Supplementing the written responses with discussions and classroom observations could provide a more comprehensive view of how students reason through SSIs. For instance, while interviews allowed us to triangulate some of our findings, the sample size was small and consisted of self-selected students. However, focus group sessions might reveal how students negotiate differing perspectives or challenge dominant discourses as they co-construct meaning. In addition, classroom observational data would have allowed us to record the types of classroom discourse generated either by the students or the instructor that may have influenced how students constructed arguments in their assignments.

A final limitation is that the students were not given structured guidance on how to evaluate and weigh evidence when forming their responses. Other studies have shown that when students are provided with explicit scaffolds, such as rating the strength of evidence or identifying tradeoffs, they tend to produce more systematic and balanced reasoning (Dauer et al., 2016; Jimenez et al., 2024). Because our prompts were open-ended, students may have focused on a single line of reasoning rather than deliberately weighing multiple forms of evidence. Future studies that integrate writing-to-learn instruction, including decision-making, could incorporate light scaffolding for evaluating evidence to see how this shapes students' use of SSC.

Implications

This study provides evidence that can help instructors better understand how students approach environmental SSIs and what kinds of socioscientific capital they draw upon when reasoning about environmental topics. Because many educators aim to use SSIs to promote ecological literacy but face challenges such as limited class time and lack of confidence in facilitating discussions, these findings offer practical insight into what resources students may use and where additional support may be needed. First, students naturally bring a wide range of SSC to their reasoning on SSIs, drawing on scientific knowledge and community knowledge (external), values and attitudes (internal), and dominant discourses (meta-level). Importantly, effective SSI teaching does not need to start from scratch; it can build on what students already know and believe. Instructors can create learning environments that acknowledge and value these diverse resources, helping students connect disciplinary content to their personal lives. A second implication is that the way an SSI prompt is framed (i.e., the perspective or role that the student takes) may shape the resources students use. In this study, when students responded from a personal perspective, they expressed their values, beliefs, and emotional connections to the issue. When framed professionally, their responses focused more on technical or disciplinary knowledge. While this study was limited by having only one prompt written from a personal perspective, and which was also a locally relevant issue, the clear difference in resource use suggests that the framing may shape what the students write about and how they position themselves in relation to the issue. Likewise, these findings may further support claims that demonstrate more elaborate reasoning when engaging with topics that have a local and meaningful context. Finally, this study demonstrates that integrating SSI reasoning into existing structure, such as weekly assignments aligned with course topics, can be feasible and informative. By embedding SSI activities within existing coursework, instructors can maintain

content coverage while offering other opportunities to develop and strengthen their ecological literacy.

TABLES

Table 3.1 Summary of frameworks describing students' knowledge systems in reasoning about SSIs.

Framework	Description	Source
Funds of Knowledge (FoK)	Students' everyday, community, and household knowledge	Moll et al., 1992
SEE-SEP Model	The knowledge, values, and practices across six domains: scientific, ethical, economic, social, environmental, and personal	Change Rundgren and Rundgren, 2010
Science Capital	Knowledge about science, attitudes towards science, science-related contacts, and dispositions	Archer et al., 2015
Socioscientific capital	The internal and external knowledge, experiences, and values that operate within broader meta-level or societal influences.	Klaver et al., 2023

Table 3.2 Codebook for Socioscientific Capital. See Appendix 2.4 for complete codebook.

Resource Level	Resource Type	Description
Internal	Knowledge	Scientific, common, or context-specific knowledge applied to the issue
	Experience	References to lived experiences or daily life events
	Values	Deeply held principles or moral commitments guiding judgments
	Beliefs	Statements about what is considered true or false (can be descriptive, evaluative, or prescriptive)
	Attitudes	Positive or negative evaluations of ideas or actions
	Skills	Demonstrated or referenced reasoning, argumentation, information evaluation, or decision-making abilities
External	Academic	References to coursework, instructors, and other knowledge gained from academic settings
	Family Influence	References to parents, siblings, or extended family as informational or value-shaping sources
	Media	Influence from newspapers, social media, TV, podcasts, YouTube, etc.
	Community	Input from peers, religious communities, cultural traditions, or social groups
Meta-level	Cultural Norms	Cultural or national values, identity-based assumptions, or historical framing of issues
	Dominant Discourses	References or alignment with widespread societal narratives or ideologies

FIGURES

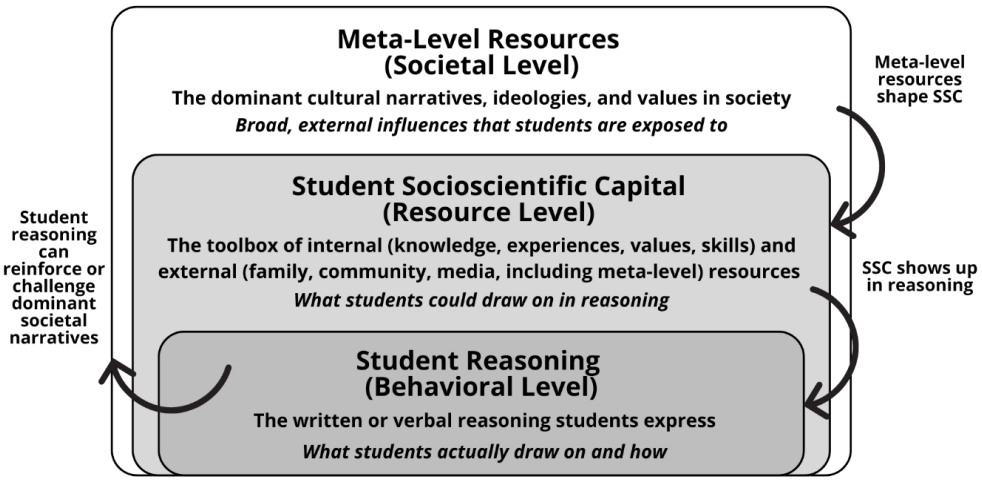

Figure 3.1 The Socioscientific Capital (SSC) framework conceptualizes the range of resources students bring to reasoning about SSIs (adapted from Klaver et al., 2023). Meta-level resources represent broad societal influences, such as dominant cultural narratives. Student socioscientific capital encompasses both internal resources, such as experiences and values, and external resources, such as community or academic knowledge, that shape what students can draw upon in reasoning. Student reasoning represents the written or verbal arguments students produce when integrating and applying these resources. The arrows indicates the relationship between these levels, showing how societal contexts influence students' available resources and how students' reasoning can also reinforce or challenge societal narratives.

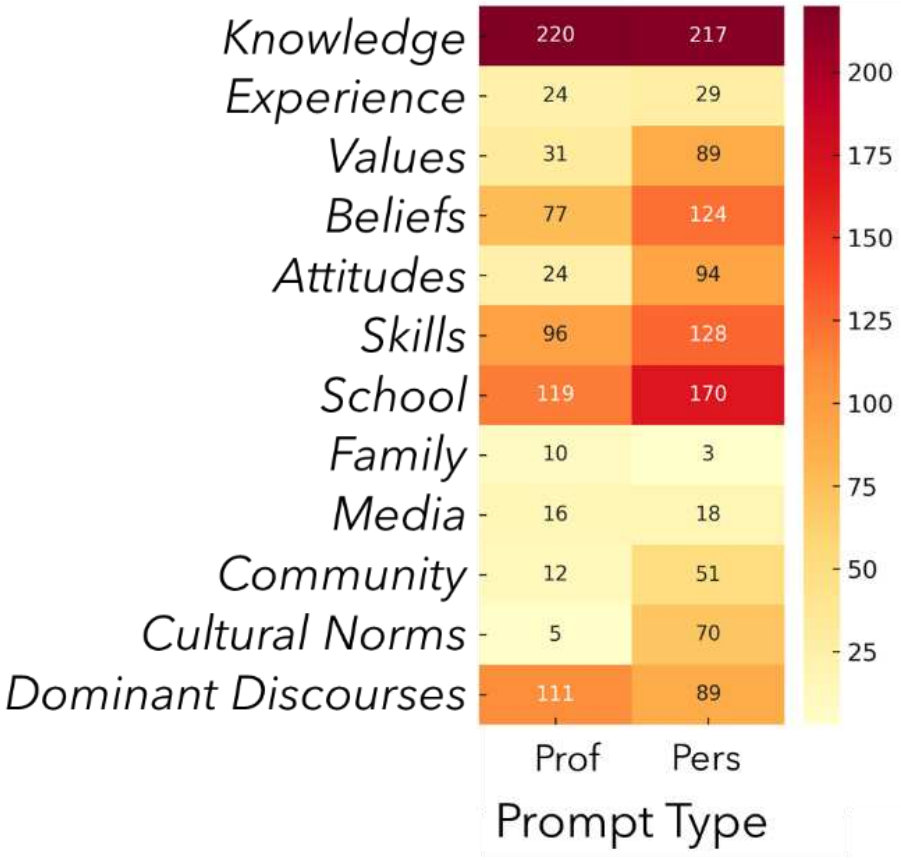

Figure 3.2 Heatmap displaying an average of coding frequencies for each capital type across both semesters. Frequencies are organized into two columns depending on whether the prompt elicited a professional role ("Prof" left) or personal role ("Pers" right).

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CHAPTER 4[3]

INTRODUCTION

Natural resource management (NRM) professionals are increasingly expected to address complex environmental issues such as climate change and biodiversity loss in ways that are scientifically rigorous yet responsive to the cultural and political contexts in which NRM occurs. Meeting these expectations requires NRM professionals to engage with communities and draw on diverse sources of knowledge (e.g., scientific, including Indigenous science, and local expertise) to inform their practice (DeFries & Nagendra, 2017; Tengö et al., 2014). In addition, recent scholarship (Elliott et al., 2018; Gibert et al., 2017; Schwartz et al., 2017) and policy frameworks (Calvin et al., 2023; IPBES, 2019) emphasize that technical training alone is insufficient; professionals must also develop and apply relational skills, such as humility, cultural responsiveness, and ethical reasoning, to navigate the social and ethical aspects of their work (Arcand, 2024; Chan et al., 2016; David-Chavez et al., 2024; Wilmer et al., 2021).

Graduate education is a formative stage during which early-career professionals integrate technical skills with professional values. These evolving expectations shape how students discover with disciplinary norms and develop their professional identities (Culver & Bertram, 2017). Yet, many graduate NRM programs continue to emphasize ecological or technical knowledge (e.g., modeling, fieldwork, and quantitative analysis) while overlooking the social and political realities that shape its practice (Slater et al., 2024). As a result, graduating students may be well-trained in disciplinary skills but be unprepared to navigate interpersonal tensions, power imbalances, or value conflicts when engaging in community-based work.

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Despite calls for NRM training to better prepare professionals for ethical and relational practice (Slater et al., 2024; Teel et al., 2022), little empirical research has examined how graduate courses that are intentionally designed around these goals have shaped students' professional identities. For graduate students, courses that integrate ethical space and reflexivity may offer new ways of understanding their future professional roles. In such courses, students may be prompted to reconsider how they position themselves in relation to others, how their training aligns with real-world practice, and how they hope to engage in NRM work that is both effective and equitable (David-Chavez et al., 2024). For some students, these class discussions may clarify their professional roles; for others, they may provoke uncertainty or a re-evaluation of previously held beliefs about NRM practice and/or their values (Kim & Wright, 2024). When scaffolded with care, through tools like reflective writing, structured dialogue, and space to process discomfort, these learning environments can support students in exploring who they are becoming as professionals, not just what they know (Millner, 2023).

The current study addresses the gap in the literature by exploring how graduate students made sense of their professional development in a community-based NRM course grounded in an ethical space for relational science (David-Chavez et al., 2024; Ermine, 2007; Wilmer et al., 2021). Using a constructivist grounded theory approach, we traced how students' engagement in course materials and interactions with others informed their evolving sense of professional identity.

THEORETICAL FRAMEWORK

We define professional identity as students' evolving understanding of themselves as NRM practitioners, including their values, perceived roles, and how they interpret and respond to the norms and expectations of the profession (Trede et al., 2012). We approach professional

identity not as a fixed set of traits, but as a dynamic construct that develops over time through experience and interactions (Downey et al., 2006). To better understand how graduate student participants in this study made sense of their professional identity, we drew on multiple theoretical frameworks that broadly explain identity as a reflexive and socially influenced process.

Our primary theoretical grounding is informed by situated learning theory (Lave & Wenger, 1991), which explains how learning occurs within communities of practice (Wenger, 2000). These perspectives frame learning as a social process through which individuals develop identities by participating in shared practices and gradually move from the peripheral to central roles within a professional community. Wenger's (2000) three modes of belonging (i.e., engagement, imagination, and alignment) explain how students make sense of their experiences and construct meaning within professional spaces. In graduate NRM courses, for instance, students may interact meaningfully with course content and peers (engagement), consider how they fit into the field (imagination), and attempt to reconcile personal beliefs with professional expectations (alignment). These processes are often messy and unpredictable (Alsup, 2006; Quaintance et al., 2025; Solbrekke & Jensen, 2006). Tension between modes of belonging, and between personal and professional values more broadly, can create discomfort and uncertainty; however, they also play an important role in identity development (Carminati & Héliot, 2022; Rothbard & Ramarajan, 2009). Learning and identity are thus intertwined: becoming a member of a professional community involves both knowing what to do and seeing oneself and being seen by others as a participant who continues to learn (Baker & Pifer, 2011).

We also draw on the symbolic-interactionist perspective of role theory (Serpe & Stryker, 2011), which explains how individuals construct and navigate roles through interaction and

interpretation. According to role theory, professional identity is shaped by both internal beliefs and how individuals perceive and respond to the expectations attached to a given role. When students experience conflict between personal values and external expectations, they may engage in role negotiation - a process of actively interpreting, resisting, or adapting those expectations (Sluss et al., 2011). Through role negotiation, students make ongoing meaning of who they are and how they fit within their professional community, especially as they transition to early career professionals (Anglin et al., 2022). These theoretical lenses are especially relevant in complex learning environments, where expectations are often ambiguous, and students must reconcile disciplinary norms with their evolving identities.

METHODS

Study Context

This study was conducted in a graduate-level natural resources course at a land-grant university in the Rocky Mountain region of the United States. The course was designed to provide students with historical, theoretical, and applied knowledge of community-based natural resource management approaches. Students in the course (n=20) were pursuing master's (professional or thesis-based) or doctoral degrees across several university departments, with many engaged in interdisciplinary research, including sustainable development, environmental governance, human dimensions of wildlife conservation, science or Indigenous science education, and natural resource tourism. The course met once a week for a 3-hour seminar that was organized into thirteen weeks of student-led discussions and activities. Course reading materials were selected both by the instructor and the students leading the specified seminar (see Supplemental for weekly course topics). Although this was the instructor's first time teaching the course, she had previously taken it as a graduate student at the university and had guest-taught

for multiple years, providing her with familiarity with its structure and content. CBNRM is the focus of the instructor's research program.

Data Collection and Analysis

Constructivist grounded theory (CGT) (Charmaz, 2017) guided the design of this study. CGT highlights how meaning-making is influenced by the researcher's positionality and the socio-historical context of the study. Charmaz (2017) argued that researchers bring prior knowledge and theoretical exposure to their work, and that we need to be aware of how these may influence the analysis. In this study, the researchers' familiarity with identity theory and experience in the course provided insight into students' experiences without predetermining outcomes. For this reason, we found CGT to be well-suited for exploring how professional identities take shape within a complex learning environment.

We collected multiple forms of qualitative data (approved under IRB protocol no. 4235), including course artifacts, formal and informal interviews with both students and the instructor, and field notes recorded during the 15-week semester and over two years total following the course. Students contributed to an online discussion board, responding to course readings and extended in-class discussions to share resources that helped them to understand the topics better. Students submitted multiple short papers and a final synthesis project, which served as evidence of their conceptual understanding and evolving professional identities. They also submitted a positionality statement that identified their relationship to their work and that addressed their goals, identity, and status (i.e., power, roles, and privileges) as future NRM practitioners and/or researchers.

The first author conducted semi-structured interviews with the course instructor and three students, and throughout the semester, met informally with all the course participants. The semi-

structured interview format allowed us to be flexible in exploring key themes while ensuring consistency across participants (Brinkmann, 2014). A formal interview with the instructor was conducted at the end of the semester, while student interviews took place 1.5-2 years later, when they could reflect on how the course shaped their professional identities (See supplemental for interview protocol). All formal interviews (totaling 275 minutes) were recorded and transcribed for analysis. To protect the anonymity and confidentiality of the students, all names presented are pseudonyms.

Participant observation, an essential aspect of grounded theory research, was particularly valuable in this study. Unlike interviews, which rely on self-reported reflections, observations allowed us to record how students engaged with course material, peers, and moments of tension, providing a more contextualized understanding of professional identity formation (Lareau, 2021). The first author, who was both a student and participant-observer in the course, documented in-class experiences and informal focus group sessions throughout the semester. Focus groups were initiated by students who wanted to continue course discussions in a more relaxed, off-campus setting. While all students were invited, only a small subset of the students attended each time. Focus group conversations, although unstructured, often focused on topics that provoked identity-related tensions in class, giving students space to reconcile their evolving identities in a collaborative environment.

Data analysis followed Charmaz's (2017) CGT approach, using an iterative coding process to identify themes. Constructivist grounded theory explicitly acknowledges that researchers and participants may not share epistemologies, necessitating that the research team adopt a reflexive approach and pay attention to the social context of meaning making (Charmaz, 2017). The first author had developed a good rapport with the other participants and instructor,

allowing her to engage in regular informal discussions with them outside of the class. All data were imported into MaxQDA (version 24.8.0), a mixed-methods analysis software, to facilitate systematic coding. During the initial coding phase, line-by-line coding was conducted for course artifacts, interviews, and field notes to capture patterns in professional identity development.

The authors engaged in regular peer debriefing and, as coding progressed, we identified strong alignment between our emerging themes and an existing codebook developed by Carminati and Heliot (2022), which originally examined identity conflicts of healthcare professionals in ethically charged situations. Given the conceptual overlap, we adapted their codebook, refining categories to better fit our dataset while preserving the integrity of the original framework. We present the findings through cases to illustrate the complexities of participants' professional identity development (Witz et al., 2001). This narrative approach allows us to reflect on the ways identity development unfolded, often in non-linear ways, and in response to evolving tensions.

Author Positionality

We recognize that our own identities, backgrounds, and experiences shaped the design, analysis, and interpretation of this study. The first author, a white, first-generation woman in higher education, was both a student and a researcher in the course. This dual role provided valuable insight to the students' classroom experience, but also required ongoing self-reflection to recognize potential biases (Musante, 2014). As a trained ecologist transitioning into science education research, she underwent identity development during the study, grappling with shifting views on knowledge and values in addressing socio-ecological problems. These experiences informed her sensitivity to students' reflections and deepened her awareness of the complexities of identity development in the course. The second author, the course instructor, is a multicultural

Indigenous woman professor and research scientist, also first generation in higher education, working to address gaps in Indigenous curriculum and pedagogy within the natural resource sciences. The anchoring author is a science education researcher and professor who was a mentor of the course instructor when she was a graduate student. She touched base with the instructor during and after the course about her perceptions of the ongoing analysis, to engage in member checking. This author identifies as a woman of color, daughter of immigrants, and someone who continually navigates different worldviews across academic and professional spaces, affording insight into the course objectives and experiences of the participants.

RESULTS

This study examined how graduate students in an NRM course that was grounded in ethical space and reflexivity made sense of their professional identity development. A key finding was that, through course topics and discussions, identity tensions surfaced. These moments were when students explicitly experienced a conflict or misalignment between their personal values, roles, or lived experiences, and the professional expectations, assumptions, or worldviews introduced through coursework and peer dialogue. We refer to students' recognition of these tensions as *Identity Perception*, the first of three dimensions in our conceptual model of NRM professional identity development (Figure 4.1).

How students responded to these tensions - affectively, cognitively, or behaviorally - played a pivotal role in shaping their professional identity development. These *Identity Responses* varied widely, from initial discomfort or defensiveness to intentional reframing and greater engagement with questions of power and ethics (Figure 4.1B). In turn, these responses informed students' *Long-term Outcomes*, or how they imagined their future work, relationships, and responsibilities in the field of NRM (Figure 4.1C).

We present the findings through two cases, Ross and Lola, whose reflections, writing, and classroom participation illustrate how professional identity development unfolded over the semester. While the experiences of all students informed the development of our theoretical model, Ross and Lola were selected as focal cases due to the depth and nuance of their reflections. Their cases illustrate the professional identity transformations that some students experienced in the course. Ross and Lola's backgrounds differed in meaningful ways, but they also shared similar identities and privileges that made questions of power, legitimacy, and responsibility especially salient. We present their cases through three themes for clarity (i.e., perception, response, outcomes) to trace how different aspects of professional identity development emerged.

Ross

Ross was nearing completion of his professional science master's degree in natural resources stewardship at the time of the course. He brought a wealth of cross-cultural experience to the classroom, shaped by an international upbringing and several years working on collaborative conservation projects with Indigenous communities in Alaska - experiences he frequently referenced both in discussions and written reflections. Although Ross was a non-traditional student returning to graduate school to start his professional career, he also held dominant social identities within the academic setting (e.g., "white male"), which he openly acknowledged as sources of power and privilege.

Perceiving tension: internal and interpersonal

Early in the course, Ross was already questioning who has a legitimate role in community-based NRM, and how that role should be taken responsibly. In a discussion post, he asked, *"Based on past harms, is it even ethical for [a white man] to work in Indigenous*

spaces?" This question reflected a sense of dissonance between his personal identity and the systems in which he had been trained. He followed up asking: *"Can the demonstrated understanding and allyship of 'an identified oppressor' contribute to building an ethical space in which they may work within an Indigenous community?"* This question reflects Ross's early confrontation with the history of exclusion and exploitation in the field of natural resources – issues which he also explored in another NRM course that centered on natural resource rights and reconciliation, taught by the same instructor. Rather than assuming his participation was neutral or beneficial, he examined whether his social positioning might unintentionally reproduce harm. Ross continued to explore throughout the course how to reconcile his desire to contribute meaningfully to community-based NRM while navigating the ethical complexities of doing so as a white man working in Indigenous spaces (Figure 4.1A).

Ross's questioning extended to his understanding of his professional path. In another reflection, he shared,

> *I have extended this even further to believe that I do not have any justified claim to work in natural resources in any capacity… Maybe I need to come to terms with the fact that I quite possibly came back here to unlearn more than to learn.*

Here, Ross explicitly reframed the purpose of graduate education - not simply as a place to gain expertise or technical skills, but as a space to shed assumptions and inherited frameworks. Ross's shift in professional identity illustrates identity negotiation that can occur when people confront tensions between disciplinary norms and their own values (Sluss et al., 2011). Rather than retreat from this discomfort, Ross began to see value in abandoning certainty and adopting a more reflexive stance. In other words, his ability to be metacognitive allowed him to demonstrate intellectual humility, acknowledging that one's initial beliefs and knowledge can be challenged and even replaced with other conceptions (Fischer et al., 2025).

Affective response

Ross's reflections show how emotionally charged his realizations were (Figure 4.1B). In looking back on his previous work with Indigenous communities, he wrote, *"I didn't appreciate it then, but I certainly do now… I know I could have been a better advocate and ally."* The course helped him identify a tension he had previously felt but had not thoroughly examined, particularly the limitations of having good intentions when working in cross-cultural contexts. At times, this reflection led to broader questioning. He wrote, *"In retrospect, it now seems foolish to return to the very same settler-colonial institution that failed me in the first place,"* expressing doubt about whether academia was still a viable learning space for him. These affective responses (e.g., frustration, regret, uncertainty) suggest that, during the course, Ross was actively reassessing his place within the NRM field. As he shared later in the semester, *"Personally, this is something I struggle with a lot. So much so that I have been considering changing my career path just as I entered the last semester of my degree."* Ross's reflexivity illustrates how moments of identity tension can surface in the classroom but extend well beyond it. For Ross, the course resurfaced unresolved questions about whether his values and positionality aligned with his aspirational professional field and whether staying in that field was still the right path forward.

Cognitive response

Despite this discomfort, Ross remained engaged in the course. Over time, he began to reframe his role - not by distancing himself from his past work, but by interpreting it differently (Figure 4.1B). *"I now recognize the shortcomings of my understanding and the harms of my entrenched identity,"* he wrote. *"With that in mind, I have begun to develop the tools and understanding to better operate within an ethical space."* This quote captured a turning point in Ross's response: from emotional uncertainty to reflection. Importantly, he did not claim

resolution or mastery. Instead, he identified the need for tools (e.g., language, frameworks, and practices) that can support more thoughtful engagement in ethically complex settings. This illustrates what we identify as a cognitive response: the process of making sense of one's role by learning to engage with privilege more responsibly rather than erasing or ignoring it.

In his final synthesis project, Ross revisited his earlier conservation work and described it as valuable, but incomplete. He reflected, *"I wish my own understanding on these matters was more robust at the time I began [my prior work]."* While Ross had long demonstrated humility and self-awareness, this statement pointed to a growing recognition that natural resource management requires being humble and learning about the values and belief systems of others. For him, meaningful practice increasingly meant making intentional space for worldviews beyond his own.

Behavioral response

As Ross developed a deeper awareness of ethical engagement and the importance of centering others' perspectives, his understanding began to translate into action (Figure 4.1B). He initiated a course-wide conversation on language and respectful communication, writing:

> *It is clear how vital it is to be able to talk about concepts and worldviews in a welcoming and respectful manner… I would therefore humbly like to ask you all if you could offer some guidance on the language one might use.*

Rather than internalize his uncertainty, Ross turned it into a public, relational act of inquiry – an example of how professional identity is constructed through participation and shared meaning-making within a learning community (Lave & Wenger, 1991). His statement represents a behavioral response rooted in vulnerability and a willingness to invite collective learning. McNamee and Moscheta (2015) describe this as relational intelligence, or the capacity to respond to others with humility. Ross's openness encouraged his peers to reflect on their

communication practices and share their uncertainties. He also contributed resources from previous fieldwork and remained actively engaged in class discussions, offering support while making clear that he, too, was still learning. The balance between sharing knowledge and acknowledging limitations became a signature of Ross's participation in class activities.

Long-term outcomes

By the end of the course, Ross no longer questioned whether he belonged in the field but focused instead on how he might contribute (Figure 4.1C). He wrote, *"I hope to demonstrate that, in fact, I do have some value, however slight, as a practitioner in the natural resource field."* His comment reflects his underlying humility, coupled with a desire to remain engaged. Like Ross, some students may leave their NRM courses with a more grounded sense of purpose that fosters unpretentiousness, reflection, and accountability. His final project was framed as both a class product and a resource to share with his former colleagues. *"It is my hope that I may use the powers and privileges of my person as well as those embedded within [my institution] to openly share this information in a more applicable format."* We concluded that Ross's participation in the course shaped his self-perception, sense of professional responsibility, and the kinds of work he hoped to do moving forward.

Lola

At the time of the course, Lola was pursuing a research master's degree in NRM and public policy. She brought nearly a decade of experience as a writer and facilitator, along with a deep connection to "*place*," shaped by her rural upbringing. Lola often reflected on her position as a non-Indigenous person working in a field shaped by colonial histories. Her interests in forest restoration, Indigenous sovereignty, and inclusive policymaking were rooted in both personal experience and professional goals. While she held several dominant identities, Lola approached

her graduate work with a strong awareness of historical injustices and a commitment to fostering more equitable NRM partnerships.

Perceiving tension: internal and interpersonal

Lola entered the course with an existing awareness of social inequities, but her participation prompted a deeper reflection on how privilege shaped her academic and personal life. In her interview, she reflected, *"It took the whole 15 weeks to shift white privilege from a bad, nasty thing to something that I need to be aware of."* Lola did not just acknowledge her privilege but actively redefined it from a source of shame to a call for responsibility. She recognized that privilege was not inherently negative, but that ignoring it could lead to harm. This internal shift illustrates a core identity tension that many students experienced: moving from discomfort with possessing unearned advantages to a sense of awareness and ethical responsibilities.

Lola experienced tension during classroom interactions. She described feeling alienated at times by peer-led conversations that felt "*righteous*," noting that these moments made belonging, what she described as "a sense of ease and ability to be who you really are," hard. She contrasted these experiences with the instructor's ability to "*hold space,*" the act of creating supportive and judgment-free zones, for growing through discomfort. This highlights the importance of facilitation and classroom culture in mediating identity tension. The course structure allowed Lola to reflect on how interpersonal dynamics among peers and between students and instructors influence students' willingness to confront complex topics (Figure 4.1A).

Affective response

Lola's emotional reactions to class interactions and materials revealed how her feelings evolved throughout the course (Figure 4.1B). When encountering readings and conversations about Indigenous sovereignty and local stewardship, she recalled, *"It felt like… maybe all the white people should go home. And that was so disturbing to me."* Her discomfort stemmed from a deep sense of displacement and personal history. As she explained, *"My great grandparents came here to escape Mussolini and famine. And I don't have a place to go back to. Like, this is the place."* Rather than disengage, Lola pushed back on the discomfort and used it as an opportunity to reflect on her own identity and belonging. These affective responses (e.g., disturbance, discomfort, and eventually gratitude) revealed a shift in how Lola processed her layered emotions. Over the semester, Lola began to reframe her feelings of guilt as opportunities for growth: *"[This course] made me… be a little bit more aware of my own privilege… I am so grateful."* As she developed a stronger awareness of the systems that had shaped her learning, Lola expressed appreciation for the histories and responsibilities tied to her privilege. Her evolution mirrors Ross's experience, where emotional tension served as a bridge to deeper reflection.

Cognitive response

Lola began to rethink the way she had written about and represented cross-cultural experiences (Figure 4.1B). Discussing a piece she had written about a prior field experience, she explained, *"Most of what I had written… was, I don't want to say trivializing, but it was a centralizing [of] the communities and traditions that I had observed."* It is common, especially for students early in their careers, to center their own perspective when interpreting experiences (National Research Council, 2000). What made Lola's reflection significant was her growing awareness of how centering particular identities can reproduce power imbalances. The course

helped her see that her writing may have reflected the dominant cultural lens in which she lived and was trained, rather than integrating the perspectives, knowledge systems, or lived experiences of the communities themselves. In doing so, she recognized how she may have unintentionally portrayed communities as passive subjects of observation, rather than active knowledge holders or collaborators.

Lola also reflected on how intersecting aspects of her identity shaped how she moved through the world and her field of work. *"It is frustrating for me to consider giving up the power I have fought for as a woman,"* she wrote,

> *but, I realize I can learn from this experience to practice giving up power as a white person by listening, doubting my rightness, asking for input, putting the needs of others before my own. I can maintain my woman power but give up my white power.*

This statement illustrates how Lola grappled with layered forms of privilege and marginalization. Rather than oversimplifying her identity, she began to see how ethical engagement required maintaining agency in some contexts while stepping back in others and acknowledging how intersectional identities can shape other people's experiences. Lola's growing awareness represents a cognitive shift towards intellectual humility - a reframing of what it means to observe, represent, and write about other communities, especially in NRM settings. She also recognized the limits of her previous knowledge, noting that what she initially saw as comprehensive was incomplete or reductive. This mirrors other students' movements from perceived expertise to humility.

Behavioral response

Lola's reflections led to tangible changes in how she approached her roles as both an educator and a researcher (Figure 4.1B). *As an educator with the undergrads that I teach… and then soon someday a practitioner… [I'd work] to rebalance the scales,"* she explained, referring

to her growing commitment to equity and justice in NRM. These statements point toward behavioral intentions that extend beyond the classroom. Lola understood that her future role in collaborative governance was inseparable from her identity and that ethical practice would require continuous attention to power and responsibility. This was also reflected in how she revisited her positionality statement, a course assignment she continued to use as a tool for ongoing reflection. She shared, *"I have used my positionality statement to understand what is that big picture about who I am."* Lola's awareness of her professional identity unfolded gradually, as she revisited and refined how she understood her place within the field.

Long-term outcomes

By the end of the course, Lola's reflections indicated a shift from self-consciousness about privilege to a more proactive and relational form of responsibility. Rather than expressing a desire to resolve all tensions, she articulated an ongoing commitment to learning, ethical practice, and supporting others in doing the same (Figure 4.1C). Her experience illustrates that professional identity development is a combination of building skills and developing a practice of self-awareness and accountability within relational contexts. While Lola's trajectory mirrored Ross's in some ways, particularly in how affective responses drove cognitive and behavioral change, her reflections also highlighted the nuance of navigating growth in spaces where peer dynamics and institutional structures can feel exclusionary. Her story highlights the role of structured, supportive learning environments in making identity development sustainable (Millner, 2023).

DISCUSSION

This study aimed to explain how graduate students in NRM made sense of their developing professional identities when challenged to consider historical power dynamics

embedded into sociocultural systems. In our grounded theory study, we examined professional identity development in response to class discussions about conflicting worldviews, social roles, and professional expectations. The cases of Ross and Lola offer contrasting insight into this process. While both students experienced identity tensions, their entry points and pathways diverged in meaningful ways. Ross was quick to express humility and empathy, often referencing his prior experience working with Indigenous communities. His reflections showed a readiness to decenter himself and take responsibility for his future role as a practitioner. In contrast, Lola initially centered on her own experiences of marginalization, and her reflections were slower to expand beyond personal discomfort. It was only later in the course that she reframed her awareness of privilege. These differences suggest that students reference their background and experiences during identity-shaping moments, and that these influence the pace and trajectory of their development. Still, both cases affirm what others have observed about how professional identity takes shape. Trede and colleagues (2012) emphasized that identity development often happens through meaningful reflection, moments of tension, and experiences that challenge students' worldviews. They explained that transformation can begin when students are asked to reconcile competing ideas or question their assumptions. This was true for Ross and Lola; the identity tensions they experienced prompted a deeper reflection about how their personal identity intersects with their professional one (Figure 4.1). These shifts did not happen in isolation but were supported by a learning environment that created space for students to reflect on and wrestle with difficult questions and grow through them.

Courses that intentionally integrate technical competencies (e.g., mapping resources or designing surveys) with relational science, and ethical spaces for engagement, such as the one presented here, offer a promising response to the limitations of conventional academic training.

While traditional NRM curricula emphasize technical and disciplinary skills, they often neglect the social, emotional, and ethical dimensions of conservation practice (Slater et al., 2024; Teel et al., 2022). In contrast, the instructor of this course intentionally made space and time for students to examine systems of power and knowledge and develop new ways of engaging with community-based NRM challenges. Ross's questioning of his social identity and Lola's reflections of the power she holds and how she uses it both illustrate how relational and ethical competencies can be developed when they are explicitly integrated into course design.

When new information challenges students' deeply held beliefs or sense of self, they may experience cognitive dissonance (Festinger, 1957). Dissonance often leads to affective responses such as discomfort, guilt, or shame, particularly for students with historically privileged identities (Zembylas, 2022). Ross's expressions of regret and doubt, including his questioning of whether he belonged in the field at all, reflect these affective consequences. Lola, too, shared moments of emotional conflict, particularly when confronting how she had previously written about other communities. These tensions were not resolved by the course but were supported through facilitation that invited vulnerability, reflection, and growth.

Students' responses to these tensions were consistent with theoretical models of dissonance. Research suggests that students may respond cognitively (by reframing their beliefs) or behaviorally (by changing how they act) when experiencing discomfort (Balaman, 2020; Walton, 2011). Ross engaged in both, reassessing his past fieldwork and initiating conversation about respectful language. Lola demonstrated similar cognitive shifts, articulating a more layered understanding of privilege and power, and described how she changed her teaching practices as a result. Both Ross's and Lola's case studies demonstrate productive outcomes of identity tension between personal and professional identities. However, as some scholars caution, such

engagement is not guaranteed (Bergkamp et al., 2022; Watt et al., 2021). Without adequate support, students may deflect, intellectualize, or disengage – an outcome that is particularly concerning for future NRM professionals, who often must navigate diverse community contexts (Bergkamp et al., 2022). Avoidance or superficial engagement with these identity tensions can limit students' readiness to build trust and other core competencies for equitable NRM practice.

Recognizing the challenges that can arise when students confront identity tensions, scholars have emphasized the need for instructors to address and respond to discomfort with care. Millner and others (2023) argued that identity development in justice-oriented classrooms requires more than critical content but also scaffolded instructional strategies that help students process emotionally complex material. Drawing on their own experiences, they recommend adopting shared languages and creating "practice zones" for students to experience vulnerability without trauma, although this may not be sufficient for all students. The instructor of the course described here addressed this challenge directly, offering students multiple opportunities to engage in reflection, dialogue, and feedback. Lola's case especially highlights how facilitation style, class culture, and peer dynamics can shape whether students feel safe enough to explore complex topics. Ross's trajectory, from self-doubt to reflective re-engagement, illustrates what can happen when identity tension is met with space for self-examination. His story highlights how discomfort can become a driving force when students are supported in working through identity development, rather than pushed to resolve it too quickly.

Locus of Control as an Interpretive Lens

While this study foregrounds identity tensions as key moments in students' professional development, additional interpretive lenses may help explain the variation in how students responded to those tensions. One such lens is locus of control – a concept describing whether

individuals tend to attribute outcomes to their own actions (internal locus) or to external forces such as luck, history, or figure of authority (external locus; Rotter, 1975). Though not the focus of our original analysis, this framework offers a helpful way to understand why some students appeared to re-engage with discomfort productively, while others intellectualized or distanced themselves from it. Ross and Lola, for example, both demonstrated what could be interpreted as a growing internal locus of control over the semester. Ross began the course unsure of whether he belonged in the field, but gradually reframed his background as a strength and source of contribution. This shift reflected his belief that he was agentic in shaping his role. Lola, by contrast, initially framed privilege as a fixed, negative condition (i.e., external locus) – something that was imposed upon her and shaped how others perceived her. However, over time, she came to see that awareness of privilege could be a foundation for ethical responsibility. In both cases, students came to see themselves as active participants in their own development.

Locus of control may help explain why these students were able to move through identity tensions in productive ways. Those with a stronger internal locus may be more likely to see discomfort as something to work through, believing that their own values and actions matter (Anderson et al., 2016). In contrast, students with a more external locus of control may perceive these tensions as fixed or overwhelming, shaped by systems or identities they feel unable to influence. In such cases, students may disengage, resist, or stall in their professional development (Bergkamp et al., 2022). This interpretation aligns with literature emphasizing the importance of agency in how students engage with and make meaning of professional expectations (Trede et al., 2012). Future research should explore this relationship more explicitly, examining how beliefs about control and agency shape NRM professional identity formation in complex learning environments.

Limitations

This study provides a rich, grounded analysis of identity development in a graduate NRM course, but several limitations should be acknowledged. First, the presented findings are based on an in-depth analysis of two student cases, Ross and Lola, whose experiences were particularly illustrative of identity tension and response. This focus on depth rather than breadth is consistent with grounded theory methodology but may limit the generalizability of the findings (Hussein et al., 2014). Other students may have experienced less visible or different forms of identity work not captured here. Furthermore, both students shared similar demographic and academic backgrounds: they are "white" graduate students who had previously worked or were currently working in Indigenous or cross-cultural settings. Their experiences highlight the identity development of students with historically privileged identities (Watt et al., 2021). This focus limits the ability to speak to how identity tensions may manifest differently for students from marginalized backgrounds, who may encounter distinct challenges or forms of engagement. As Kim and Wright (2024) found, students with identities that have been traditionally excluded or underrepresented in the sciences may feel validated by the curriculum but simultaneously burdened by the expectation to represent or explain their lived experience. These dynamics can significantly shape how identity tensions are experienced and processed. Future studies should examine how identity tensions unfold across a broader range of student experiences, with attention to cultural communities, gender, class, and other intersecting factors. Another limitation is that the findings are necessarily bounded by the instructor's pedagogical approach and course design. The reflexive and relational focus of this course may have uniquely supported the perceptions and responses observed here. Different instructional approaches (e.g., traditional, content-driven) or instructor teaching styles may elicit different patterns. Thus, these findings

should be interpreted within the context of this specifical instructional environment rather than as representative of all graduate NRM programs. Additionally, the first author's dual role as both participant and observer inevitably shaped data interpretation. While steps were taken to ensure trustworthiness (e.g., peer debriefing, memoing), the author's positionality influenced how she coded and framed students' reflections. As someone with a professional background in conservation and a strong commitment to inclusive and equitable practices, this author shared overlapping values and experiences with Ross and Lola. However, her professional identity development was more aligned with Lola's, both in terms of gender and in experiencing moments of discouragement or marginalization. This similarity may have contributed to a more empathetic analysis of Lola's development. Finally, this study does not fully explore how institutional, cultural, or cohort-level factors beyond the classroom may have influenced students' identity development. Future research might examine how program design, faculty mentorship, and broader departmental climate contribute to or constrain this process.

It is also important to consider potential critiques. Some may argue that centering identity development risks detracting from technical skill-building (e.g., field sampling methods or statistical analysis) in NRM education. However, we contend that ethical and relational competencies are not separate from technical expertise, but integral to effective practice in collaborative, community-driven work. Still, this argument and shift to more comprehensive professional training will benefit from continued empirical testing across diverse educational settings and student populations to better understand its broader application.

Implications

This study affirms that professional identity development is a dynamic process shaped by worldviews, social positioning, and professional norms. In graduate education, especially in

applied fields like NRM, students are simultaneously learning content and skills while navigating who they are and how they want to engage with and contribute to the profession. Ross and Lola's experiences show that this involves emotional labor, critical reframing, and behavioral change. Graduate programs that aim to prepare ethical practitioners must therefore recognize identity development not as peripheral but as central to professional formation.

Findings from this study suggest that instructors can further support professional identity development by actively drawing on students' prior roles and lived experiences. Ross's background working with Indigenous and marginalized communities appeared to support his early adoption of relational humility and ethical engagement. Lola's experience in community-engaged research ultimately shaped her understanding of how her positionality could either perpetuate or disrupt inequity. These cases highlight how students' past experiences can serve as valuable entry points for reflection and identity negotiation, especially when instructors are attuned to them. Creating space to connect their experiences to professional learning may help students build identities that prepare them to engage more intentionally with the complex, collaborative realities of the profession they are entering.

FIGURE

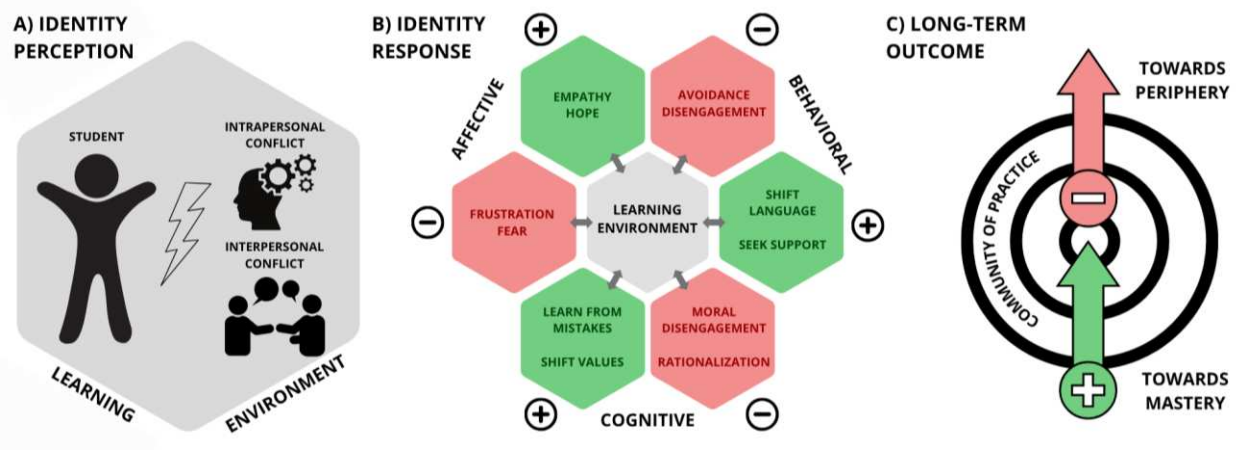

Figure 4.1 A conceptual model of professional identity development within a community of practice (CoP). (A) Throughout the semester, students encountered tensions within their own values or knowledge (intrapersonal) or in their relationships and communication with others (interpersonal). (B) The learning environment shaped and was shaped by students' affective, behavioral, and cognitive responses to these tensions. (C) By the end of the course, students who felt supported within the learning environment and responded constructively tended to express increased belonging and movement toward a more legitimized identity within the CoP (+). In contrast, students who felt unsupported or responded destructively tended to experience reduced belonging and moved toward the periphery of the CoP (-).

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CHAPTER 5

In this dissertation, I argue for ecology and environmental education research to view reasoning as a culturally mediated process shaped by students' worldviews, resources, and social contexts. The integrative model presented earlier (Figure 1.3) offers a framework for connecting individual meaning-making within the larger societal narratives and more localized classroom dynamics that shape how students interpret environmental problems. By situating reasoning within this layered system, science education researchers can identify instructional strategies and further research that better support the goals of ecological literacy.

An important implication of this dissertation research is that reasoning about environmental SSIs requires structured opportunities for students to connect diverse ways of knowing. Students may experience tension or exploration when reasoning between the affective, cultural, or moral dimensions of their worldviews and the objectivity emphasized in science curricula. Instructional approaches that acknowledge student experiences can deepen their ability to engage in critical thinking. Pedagogical strategies such as writing-to-learn (WTL) activities (Balgopal et al., 2012; Balgopal & Wallace, 2009; Balgopal & Wallace, 2013), small-group discussions (Bennett et al., 2010; Pollock et al., 2011), and reflective journaling (Balgopal & Montplaisir, 2011; Epp, 2008) can help students articulate and negotiate the interaction between these knowledges. When students can see what they know through WTL activities, they can reflect on their arguments about SSIs. Consequently, instructors can also see how students are thinking about SSIs and making decisions when they assess students' written responses.

While the model (Figure 1.3) presented in this dissertation clarifies theoretical linkages between culture, worldview, and reasoning, several empirical questions remain. First, future

research should explore how worldviews develop and transform across contexts and time. Longitudinal studies that follow students across multiple courses could demonstrate if and how worldviews filter different SSC as students' disciplinary identities mature. Second, there is a need to investigate how classroom discourse and assessment practices enable or constrain resource use. For example, discourse analysis (Gill, 2000) could examine how instructors' feedback or instructional approaches reinforce objectivity norms that disincentivize value-based reasoning. Similarly, future work might explore whether explicit metacognitive instruction (e.g., prompting students to identify which resources they drew upon) influences the diversity of SSC in their reasoning (Santangelo et al., 2021).

Future research should also explore how students learn to connect social and ecological dimensions of environmental problems through data-driven, systems-oriented instruction. Many ecological challenges, such as land-use change, require an understanding of how human and natural systems influence one another (Bergan-Roller et al., 2018; Gilbert et al., 2018). Integrating social and environmental data into classroom settings could reveal whether certain ways of knowing or worldview orientations help students recognize these connections and understand how changes in one part of a system can affect the system as a whole.

One promising direction is to design curricula that use large-scale, real-world datasets (for example, from the National Ecological Observatory Network and NASA's Socioeconomic Data and Applications Center) to help students examine ecosystem processes alongside social variables such as demographics or land-use history. Engaging with authentic, "messy" data can develop students' data literacy while also fostering a more holistic understanding of social-ecological systems (Brewer & Gross, 2003; Gould et al., 2014; Langen et al., 2013). When students analyze complex, multiscale datasets, they might begin to see how ecological and

human factors interact, which can help them develop an integrated form of ecological reasoning. This approach also positions students as data users and decision makers, mirroring the practices of professional scientists and environmental managers.

Beyond the classroom, there is a growing need to understand how students' reasoning and worldview development translate into their professional and civic lives. The same systems that shape students' reasoning about environmental SSIs in coursework may also influence how they engage with conservation, sustainability, and policy decisions. Future research could examine how early-career scientists or natural resource professionals draw on their worldviews when navigating their work. For instance, studies might follow students into field-based internships or community partnerships to explore how they apply or adapt the reasoning strategies they learned in coursework. The findings could inform how educational experiences scaffold the development of professional identities and which kinds of learning environments best prepare individuals to engage productively across cultural and disciplinary boundaries.

This dissertation points toward a broader vision of ecological literacy that integrates knowledge, values, and action. Developing ecological literacy thus involves understanding ecological concepts as well as the ability to think systemically, evaluate evidence, and reflect on how worldviews underlie environmental decision making. The frameworks and findings presented here offer a foundation for pursuing this vision, but realizing it will require interdisciplinary collaboration among educators, social scientists, and ecologists.

By linking research on worldviews, meaning-making, and systems thinking, future work can deepen our understanding of how people see themselves as part of, rather than apart from, the systems they study and inhabit. This shift marks a crucial step toward preparing students,

educators, and professionals to think critically and engage ethically with the environmental challenges of our generation.

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APPENDICES

2.1 – INTEGRATIVE WORLDVIEW FRAMEWORK SURVEY

Developed by de Witt, A., de Boer, J., Hedlund, N., & Osseweijer, P. (2016). A new tool to map the major worldviews in the Netherlands and USA, and explore how they relate to climate change. Environmental Science & Policy, 63, 101–112. https://doi.org/10.1016/j.envsci.2016.05.012

These survey questions were given to students enrolled in the undergraduate ecology course (from Chapters 2 and 3)

1. For me, to live a good life is...
    a. ... to support those who are oppressed and dominated
    b. ... to respect the tradition and honor my community
    c. ... to offer my unique 'gifts' to the larger whole of life
    d. ... to be independent and do whatever I enjoy
2. (select)
    a. Who I am is defined by my social position and/or my achievements
    b. I feel part of the vast, interconnected whole that is life and the universe
    c. I feel more like a citizen of the world than a citizen of a country
    d. Who I am is defined by my religion and upbringing
3. The most important thing in my life is...
    a. ... to be successful and have people recognize my achievements
    b. ... to actualize my inner potential and thereby serve the (cultural) evolution of humanity
    c. ... to do things my own way and forge my own path in life
    d. ... to be of service to my family, community, and/or country
4. (select)
    a. Science and technology can make beneficial contributions when society is actively engaged with technological developments
    b. Science and technology are often corrupted by special interests, e.g., of big corporations
    c. One of the negative effects of science and technology is that they break down people's ideas of right and wrong
    d. Science and technology are definitely making our lives healthier, easier, and more comfortable
5. (select)

a. In an afterlife we will be punished or rewarded for our actions in this life
b. I don't know what happens to us after we die
c. I believe that the evolution of our consciousness continues after our death
d. I don't believe in an afterlife of any form

6. In society...
    a. ... we should place more emphasis on art, culture, and moral development
    b. ... we should have greater respect for religious authority and tradition
    c. ... we should place more emphasis on science and technology
    d. ... we should place more emphasis on inner growth and self-actualization
7. (select)
    a. When individuals thrive and blossom, they naturally start working for a better world for all
    b. Everybody needs to take care of, and stand up for, oneself
    c. Society should offer decent care for every individual
    d. Each individual needs to sacrifice his/her desires to serve the community and society at large
8. (select)
    a. Humans can improve on nature
    b. Aware of their deep connectedness, humans and nature can work together in mutually enhancing ways
    c. When it comes to interfering with nature, mankind has no right to play God
    d. Interfering with nature is risky because it may be too complex for us to understand
9. (select)
    a. God stands far above life on earth
    b. People look at the world from different perspectives, which are all equally valid
    c. Reality is complex: it is both scientific and spiritual at the same time
    d. The universe is governed by mechanical, natural laws
10. (select)
    a. The suffering that happens to people does not have meaning but is random
    b. The suffering that happens to people is the will of God
    c. I use the pain and suffering in my life as opportunities for inner growth
    d. The suffering in the world is created and maintained by existing power structures
11. When I'm forming an opinion on an issue...
    a. ... I tend to trust scientists and other experts
    b. ... I tend to trust my own judgment, feelings, and intuition
    c. ... I tend to trust traditional or religious leaders
    d. ... I try to honor all perspectives and combine them into a larger whole
12. (select)
    a. Science is the ultimate source of trustworthy knowledge

b. Morality, art, and intuition are important for gaining knowledge about the world
c. We depend too much on science and not enough on faith
d. In order to gain understanding of the world, science needs to be integrated with other forms of knowledge, such as spiritual insight

13. (select)
    a. Things in nature are generally more perfect than those made by humans
    b. On a deep level, I feel like I am one with nature
    c. Humans should behave as protectors of creation
    d. By mastering nature, the human being can find freedom
14. I strive for...
    a. ... a sober, simple, and humble lifestyle
    b. ... a wholesome and natural lifestyle
    c. ... a diverse and expressive lifestyle
    d. ... a comfortable and fun lifestyle
15. (select)
    a. Life was miraculously created by a higher power
    b. How life originated is still unclear, despite what science and religion say about it
    c. I see the universe as a creative expression of an evolving consciousness or 'Spirit'
    d. Life was brought about through biological evolution (not steered by a higher power)
16. (select)
    a. People ascribe different values to nature, and all of them are important
    b. Nature has value because humans are able to use and enjoy it
    c. Nature has value in and of itself, even if it has no value for humans whatsoever
    d. Nature is created by God and is therefore valuable
17. It is very important to me...
    a. ... to adapt myself to others and behave appropriately and socially
    b. ... to be imaginative and express myself in the way I think and live
    c. ... to have enough money to have and do nice things
    d. ... to explore my inner world so I can live from my 'true' or 'deeper' self

2.2 – SEMI-STRUCTURED INTERVIEW PROTOCOL

These interview questions were given to students enrolled in the undergraduate ecology course (from Chapters 2 and 3)

1. How would you describe your perspective of environment-human interactions?
    a. How would you describe your worldview?
    b. How do you think your worldview may affect how you learn about science?
2. How often have you thought about or heard about socioscientific issues (like climate change) before this class?
    a. What does the term "socioscientific issue" mean to you?
3. When hearing or learning about SSIs (like climate change), what factors may influence the behaviors you take?
4. How is course changing the way you interpret socioscientific issues (e.g., as you read/listen to/watch media stories)? If so, how?
    a. How has this course, along with information you have gathered through media, affected how you might communicate about socioscientific issues with your friends and family?
5. How well do you think your own life perspective or worldview was incorporated in this course?

2.3 – HOMEWORK PROMPTS

These homework prompts were given to students enrolled in the undergraduate ecology course (from Chapters 2 and 3)

1. Imagine you have been hired as an ecologist by a federal agency (e.g., USDA ARS) to manage the EAB population. In this role, you have been tasked to draw on various evidence (e.g., biotic variables, abiotic, social-ecological, and economic). Other than the solution presented in the case scenario, what are 2 other possible solutions you might recommend? Support each of these with at least one piece of evidence from our class discussion, your own experience/observations, or any of your other academic courses. Please indicate where your knowledge is from.

2. [this question was not used for analysis in Chapter 3] Finally, the case scenario has been presented in the textbook as an "invasion" of an insect. Please explain in at least 3 sentences whether "invasion" is an accurate characterization of this ecological event. [note, there is no correct or incorrect answer for this, but we are interested in how you justify your position].

3. Your Australian colleagues come to visit you to learn about the wolf introduction program in Colorado. Unlike the Australian scenario, a top predator (the wolf) has been extirpated from Colorado for a long time. First, explain whether your personal position on wolf reintroduction aligns with that of the DNR's to support this program. Second, provide three pieces of evidence to support your position. Of these three pieces of evidence, one must come from this course, and the other two can be based on any other source (your own beliefs, experiences, other coursework, other readings, etc. [no judgement on my part!]).

4. Density of birds greatly affects transmission rates. You are a volunteer at a local nature association. Knowing what you do about the relationship between bird density and disease transmission, what is your opinion of the use of bird feeders. List some pros and cons of the use of bird feeders. Second, provide three pieces of evidence to support your position. Of these three pieces of support, one must come from this course, and the other two can be based on any other source (your own beliefs, experiences, other coursework, other readings, etc. [no judgement on my part!]).

5. Imagine you are a city planner for a large western US city (e.g., Phoenix, Las Vegas, Los Angeles, or even Denver) where water scarcity and quality are paramount issues. You are tasked by the city council to develop a plan that balances the needs of humans and the remaining biodiversity within city limits. Development is fragmenting natural areas – island biogeography and landscape theories may be relevant here. How do you balance the water needs of people with the needs of plants and animals in urbanized natural areas? Is there necessarily a conflict? There is no right or wrong response. We are interested in how you develop a short well-reasoned argument (a paragraph or two) based on sound evidence. Provide three pieces of evidence to

support your position. Of these three pieces of support, one should come from this course, and the other two can be based on any other source (your own beliefs, experiences, other coursework, other readings, etc

2.4 – CODEBOOK

Table A.1This codebook was developed for students enrolled in the undergraduate ecology course (from Chapters 2 and 3)

Overarching Theme	Axial Code	Open Code	Definition
STUDENT OUTPUT	WORLDVIEW TYPOLOGY	EXPLORER	Expresses multiple or shifting worldviews across responses
		ADAPTER	Consistently reasons from a worldview different from their survey-classified worldview; demonstrates flexibility but patterned change.
		ANCHOR	Consistently reasons from the worldview in which they were classified; worldview remains stable across contexts.
	EXPRESSED WORLDVIEW	EXP-TRADITIONAL	Upholds human-dominated, hierarchical, or utilitarian views of nature; emphasizes control, order, and authority.
		EXP-MODERN	Focuses on scientific objectivity, technological progress, and rational management of the environment.
		EXP-POSTMODERN	Questions objectivity and authority; highlights equity, ethics, and social justice in environmental decisions.
		EXP-INTEGRATIVE	Synthesizes multiple perspectives; values systems thinking, interdependence, and pluralism.
		EXP-MIXED	Combines features of more than one worldview without clear dominance.
	SOCIOSCIENTIFIC CAPITAL	INT-EXP	Personal Experience — References to lived experiences or daily life events (e.g., fieldwork, hobbies, employment).
		INT-KNOW	Knowledge — Scientific, common, or context-specific knowledge applied to the issue.
		INT-BEL	Beliefs — Statements about what is considered true or false; may be descriptive, evaluative, or prescriptive.
		INT-ATT	Attitudes — Positive or negative evaluations of ideas or actions
		INT-VAL	Values — Deeply held moral or ethical principles guiding judgments

		INT-SKILL	Skills — Demonstrated reasoning, argumentation, evidence evaluation, or decision-making abilities.
		EXT-ACA	Academic Knowledge — References to coursework, lectures, instructors, or scientific training.
		EXT-FAM	Family Influence — References to parents, siblings, or extended family as informational or value-shaping sources.
		EXT-COMM	Community / Social Groups — Input from peers, local organizations, religious or cultural groups, or other social networks. Use when the influence is direct and interpersonal
		EXT-MEDIA	Media Exposure — Influence from news, documentaries, social media, podcasts, or online videos.
		META-DISC	Dominant Social Discourses — Alignment with or critique of widespread societal narratives
		META-CULT	Cultural Norms or Frames — National or historical value systems, identity-based assumptions, or broad cultural patterns that shape reasoning.
STUDENT INPUT	CLASSIFIED (SURVEY WORLDVIEW)	SUR-TRADITIONAL	Prefers order, authority, and human control over nature.
		SUR-MODERN	Values scientific reasoning, progress, and economic development.
		SUR-POSTMODERN	Emphasizes equity, social justice, and moral responsibility.
		SUR-INTEGRATIVE	Seeks pluralism and interconnectedness among human and ecological systems.
		SUR-MIXED	Displays high alignment with multiple worldview dimensions.
INSTRUCTIONAL INPUT	PERSPECTIVE	PROFESSIONAL	Students respond from a disciplinary or role-based viewpoint (e.g., ecologist, planner, policymaker).
		PERSONAL	Students respond from their own perspective, experiences, or moral stance.
	CONTEXT	FRAGMENTATION	Habitat loss.
		PATHOGEN	Disease spread and management in ecological systems.
		INVASION	Non-native or invasive species issues.

		INTRODUCTION	Species introduction and reintroduction cases (e.g., wolf reintroduction).

4.1 – WEEKLY COURSE TOPICS

Table A.2 These course topics were covered in the graduate NRM course (from Chapter 4)

Week	Topic
2	Concepts of community, worldviews, ethics, and values
3	Paradigms, policy, and practice (part 1)
4	Paradigms, policy, and practice (part 2)
5	Forest stewardship
6	Rangeland stewardship
7	Research methods in CBNRM
8	International Indigenous discourse
10	Indigenous lands
11	Methods and tools for participatory decision making
12	Collaboration, consensus, and conflict resolution
13	Methods for CBNRM evaluation and reflection

4.2 – SEMI-STRUCTURED INTERVIEW PROTOCOL

These interview questions were given to students enrolled in the graduate NRM course (from Chapter 4)

Semi-Structured Interview Questions – Instructor

1. How would you describe your identity, including your epistemology, worldview, cultural heritage, profession, or any other thing you feel like.
2. Could you share more about your profession, specifically your position as a faculty member?
3. Could you tell me more about your community-based natural resource management course and the goals you had for the course?
4. From your perspective, in what ways has this course shaped students identities?
5. How would you describe your identity as it relates to community based natural resource management?
6. Can you please describe how language use shapes our identity?
7. How do you think group dynamics shape our language use?

Semi-Structured Interview Questions – Students

Adapted from Miles and Huberman, 1994

6. What is your current role and in what field are you *working/studying*. [Also for students: in what field do you intend to work after graduation?]
    a. Could you share more about how you entered this field?
    b. What types of courses or experiences *have prepared/are preparing* you for this role?
        i. What content, skills, or practices have been most helpful?
    c. In your opinion, what are the key values, principles, or ethical considerations that guide professionals in Natural Resource Management?
        i. Do you bring any personal values into your profession?
        ii. Are there any personal values that you feel conflict with that of your profession?
    d. Do you currently identify as a Natural Resource manager?
        i. IF YES:
            1. How long?
            2. What contributed to this?
        ii. IF WORKING WITHIN NRM AND ANSWER NO: could you elaborate?
    e. How do you define a sense of belonging?
    f. Would you say that you belong within the NRM field?
        i. How long have you felt you *belonged/not belonged*?
        ii. What contributed to this?

g. Please share any strategies or practices you have found helpful in building a sense of community and belonging with colleagues and peers in the field
h. In your view, what are the most pressing challenges and opportunities within Natural Resource Management, and how do you see yourself contributing to addressing them?

7. In the spring of 2022, you were enrolled in NR 625 Community-based Natural Resource Management. From your recollection, what were your intentions for taking the course?
    a. In Spring 2022, what were your professional goals at the start of the semester?
    b. Please describe any shifts (if any) to your professional goals by the end of the semester.
    c. Please describe what you remember about the major themes or content of the course
        i. Was this (or has this) content (been) addressed in other courses for your degree? If so, what courses?
    d. What specific readings or activities did you find important or foundational for a career in natural resource management?
        i. What about them is helpful?
    e. Did you enroll in the course to fill some gap in your skills or knowledge that you believed was necessary for your future career?
        i. IF YES
            1. What specific gaps in skills or knowledge were you hoping to fill?
            2. Did the course content fill any of those gaps. If so, in what ways?
    f. Please describe if the course introduced you to new or differing perspectives from that of your own
    g. How do you (if at all) incorporate any of the content from the course into your everyday practice or research? Or do you intend to do this in the future?
    h. In what ways did interactions with the instructor or fellow students in the course contribute to your sense of belonging and community within NRM?
    i. How did the course affect your confidence and competence in NRM?
    j. How did the course affect your professional decisions or identity (if at all)?
    k. Sometimes, instructors introduce new concepts that challenge our prior ways of knowing. If this happened in the course, please describe if you felt any tension with what you were learning and your personal or professional identity.
    l. As part of the course's final project, you were asked to submit a positionality statement which involved an intentional examination of your self-location (i.e., class, ethnicity, race, sexuality), beliefs, motivations, and worldviews. Do you think this activity had any impact on an individual's practice within NRM?
        i. Please describe your positionality at the start of the semester and how it may have changed throughout the semester.
        ii. Would you say that your positionality has evolved since completing the course?
8. Is there anything else that you'd like to share?

4.3 – CODEBOOK

Table A.3 This codebook was developed for students enrolled in the graduate NRM course (from Chapter 4)

Overarching Theme	Axial Code	Open Code	Definition
Identity Perception	Intrapersonal Conflict	Recognition of harm	Feelings of guilt or responsibility when realizing one's identity or actions may cause harm.
		Knowledge gaps	Awareness of knowledge gaps and discomfort with one's training or understanding.
		Value misalignment	Tension between one's internal values and external professional expectations.
	Interpersonal Conflict	Language concerns	Concerns about using inappropriate or insensitive terminology.
		Power awareness	Awareness of how hierarchy or privilege affects group dynamics and participation.
		Worldview clashes	Discomfort or tension arising from engaging with unfamiliar or opposing epistemologies.
Identity Response	Affective	Guilt	Feelings of responsibility or regret about past behaviors or social positioning.
		Shame	A sense of being flawed or inadequate due to one's identity or past actions.
		Frustration	Emotional irritation related to identity conflict or classroom dynamics.
		Fear or Anxiety	Apprehension about participation, judgement, or making mistakes.
	Behavioral	Peer support	Turning to classmates or mentors to process discomfort or develop understanding.
		Independent reflection	Privately seeking new knowledge or reflection in response to discomfort.
		Reconsidering profession	Questioning one's role or place in the field due to discomfort or perceived harm.

		Language shifts	Consciously shifting terminology or discourse in response to feedback or reflection.
	Cognitive	Learning from mistakes	Reframing past missteps as part of learning and ethical development.
		Value or belief shift	Change in beliefs, attitudes, or ways of understanding knowledge.
Long-term Outcomes	Applied Identity		Statements or actions indicating how students plan to carry their identity work forward into professional roles
	Professional Responsibility		Descriptions of future plans or professional intentions that foreground ethical engagement, reciprocity, or accountability.
	Ongoing Reflection		Expressions of doubt or unresolved questions about the student's place or role in the field,