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INVESTIGATING ECOLOGICAL IDENTITIES IN NONMAJORS BIOLOGY EDUCATION: TRANSFORMATIVE EXPERIENCE AS A MEDIATOR OF TRANSFORMATIVE LEARNING

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Abstract

Addressing the escalating climate crisis requires sustained and collective pro-nature behaviors. Such behaviors are most reliably predicted by ecological identity rather than knowledge or attitudes alone, so higher education institutions must seek to understand the processes through which ecological identities develop and become centralized in learners. This dissertation contributes to that understanding by examining relationships between transformative experience (TE), transformative learning (TL), and ecological identity in nonmajor introductory biology students during ecology instruction. Using a mixed methods approach across three university campuses, the study investigated: (1) the nature of transformative teaching in ecology; (2) the predictive relationship between transformative teaching strategies and student outcomes; and (3) the mediating role of TE in ecological identity formation. Qualitative data from instructor interviews, classroom observations, and documents revealed the highest presence of TE elements, followed by TL components and then identity. Quantitative analyses of pre-post student surveys (n = 199) demonstrated significant increases in student scores across all three constructs, with differences in TL by instructor. Further analyses indicated that instructor levels of TL teaching significantly predicted student TL outcomes and that students in sections with higher overall transformative teaching had significantly higher TL and ecological identity then those sections with less transformative teaching. Path analysis revealed that TE shifts mediate the relationship between TL and ecological identity shifts. This research establishes empirical connections between previously disparate constructs and suggests that pedagogical approaches emphasizing transformative elements may better promote the ecological identity shifts necessary for long-term pro-nature behaviors.

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Chapter 1: Introduction

Summary of this Study

This study explored shifts in nonmajor introductory biology students' transformative experience, transformative learning, and ecological identity through transformative teaching of ecology content. I sought to uncover the relationships between those three constructs in naturalistic settings of select cases and to determine the predictive power of transformative classroom instruction on those learner shifts. Ecological identity has been tied to longer-term pro-nature behaviors, which are needed to adapt to and mitigate further climate disaster (McGuire, 2015; Walton & Jones, 2018). However, nonmajors introductory biology learning outcomes do not include identity shifts (Brickman & Gormally, 2024), and classroom interventions that could help centralize learners' ecological identities, beyond previously explored increases in eco-literacy or attitudes towards nature, are just beginning to be examined.

Transformative experience has shown its usefulness in increasing student success, conceptual transfer, and affect (Girod et al., 2010; Heddy & Sinatra, 2013; Sparks & Darner, 2020), and Heddy and Pugh (2015) suggest that transformative experiences may accumulate to transformative learning results. Since transformative learning has been defined as shifts in identity (Illeris, 2014), I suggest a pathway of Transformative Experience ---> Transformative Learning ---> Ecological Identity shifts for learners. Baseline data about the presence of transformative teaching goals and methods in nonmajors introductory biology and about the relationship of those three constructs was needed. This dissertation begins to fill this gap in research towards the enhancement of education for sustainability and the environment. This chapter further introduces the problems this research sought to address, purpose of the study, significance of findings, key terms for this area of inquiry, and an outline of the chapters.

Statement of the Problem

The scientific community overwhelmingly supports the claims that humans are the cause of the climate change impacts we are currently experiencing. That is, our current global warming trends, increases in severe and catastrophic weather events, rising sea levels, melting ice at planetary poles, and shifts in plant and animal distributions are outside the natural cycles of earth and can be directly tied to human overhunting, habitat destruction, pollution, food systems, and release of greenhouse gases (IPCC, 2023). Climate challenges are considered by many to be a *wicked problem* – a complex issue with many stakeholders coming from different frames of reference (Lönngren & van Poeck, 2020). Learning about this complex, anthropogenic issue, the ways in which we are complicit in it, and considering the future of our planet can lead to denial or ecological anxiety instead of the changes in collective behavior necessary to mitigate these negative impacts (Clayton, 2020).

Educators covering topics related to climate change like ecology, supply chains, food systems, environmental justice, and urban sustainability must be aware of this learner freeze response to remove those cognitive and affective barriers to learning and to reach broader outcomes of a pro-nature, eco-literate citizenry (Jimenez & Moorhead, 2021). Undergraduate biology courses provide one context through which students are taught about the biophysical (ecological) systems in which they reside. Many non-biology majors ("nonmajors") take an introductory biology course for their general education science credit, so that course is an important opportunity in higher education to impact nonmajors' scientific literacy and ecological identities (Gardner et al., 2016). Because nonmajors have different interests, motivations, and identities than majors (Cotner et al., 2017; Hebert & Cotner, 2019; Knekta et al., 2020), their courses need to be designed differently to help ensure desired learning outcomes – whether

content-, affective-, or identity-related (Brickman & Gormally, 2024).

Ongoing research on how to best reach learning outcomes of higher eco-literacy and improved attitudes about nature are important, and there is evidence that these lead to pro-nature behaviors (Frantz & Mayer, 2014; Hinds & Sparks, 2008; Okur-Berberoğlu, 2018). However, other evidence reveals that these changes are contextual – dependent on social influences, ease of behavior, and/or mood – and are therefore more short-term than required to solve societal and global climate challenges (Kahn, 1999; Walton & Jones, 2018). In other words, current education for ecology, the environment, and sustainability is not working to shift learners' pro-nature behaviors in the long term. As argued by McGuire (2015) and shown by Clayton et al. (2021) and others, an identity approach, versus a focus on knowledge, literacy, or attitudes, is necessary for environmental behavior reorientation. By shifting our focus to ecological identity as a learning outcome, educators may be able to reach broader goals of a citizenry with a higher prevalence of pro-nature behaviors. However, research on how to accomplish this is lacking.

Purpose of the Study

My research sought to examine the presence of transformative teaching methods in select university sections of nonmajors introductory biology, to explore relationships between transformative teaching and learners' ecological identities, and to uncover relationships between three overlapping constructs that have not been previously studied together. My study took place in naturalistic settings using mixed methods to help answer three main research questions: 1) What is the nature of transformative teaching in the ecology unit of a sample of nonmajor introductory biology sections? 2) To what extent does instruction that includes transformative teaching strategies predict students' transformative experience, transformative learning, and ecological identity shifts? And 3) To what extent does transformative experience mediate

changes in students' transformative learning and ecological identities?

My study context was undergraduate introductory biology course sections for nonmajor in the United States. I chose this context because many college students are required to take one or more science courses (Nuhfer et al., 2016), and many times this includes a general biology course in which ecology topics, inclusive of human impacts on ecosystems, are covered (Aleknavičiūtė et al., 2023). In the absence of required courses on sustainability as part of core curricular requirements, a rarity in U.S. higher education (Vallée, 2024), college biology courses are important curricular loci from which to impact college students' and future citizens' pro-nature behaviors. I also selected the undergraduate nonmajors biology context due to my academic background and interest in the biological sciences. With two decades of experience in teaching, presenting, and conducting research in nonmajors biology in the United States, I have seen firsthand the need for enhanced education in ecology and environmental science.

Significance of the Study

This dissertation introduces three constructs from different fields of study that, in their overlap, provide a new educational perspective on helping address our world's current sustainability crises. This research's findings contribute to transformative learning theory, education for sustainability and the environment, and educational psychology.

From a theoretical perspective, it advances transformative learning by exploring its praxis in environmental education, providing another context for one of its validated quantitative instruments, and by examining identity shifts as conceptualized by Illeris (2014). To the environmental education literature, my research advances the use of ecological identity shifts as a necessary learning outcome and builds on McGuire's (2015) call to base environmental education on an identity model. For educational psychology and learning sciences researchers,

my study provides another case of the application of one of its validated quantitative instruments and begins to empirically uncover the previously unexplored relationship between transformative experience and transformative learning.

Practically, my research provides instructors, instructional designers, and curriculum developers with assessments to measure learner growth in beyond-content areas. It also emphasizes the importance of reflection as a learning activity to reach these beyond-content outcomes. In so doing, they can design activities with these concepts in mind to increase pro-nature behaviors, ultimately contributing to building a community more prepared to address urgent climate challenges.

Definition of Key Terms

Key terms used throughout this dissertation are defined here for readers to reference more easily. Each is further defined, explored, and exemplified later in the dissertation.

Ecological identity is based on psychosocial identity theory (Burke & Stets, 2023; Walton & Jones, 2018). It is a type of self-concept encompassing how people see themselves in relation to the natural world and how they verify that identity with others. It is considered a central, or *person* identity that can be activated across contexts, unlike *partial* identities, like family, work, or political identities that are contextual and more fluid over time.

The term *pro-nature behavior* is used in my dissertation as an umbrella term to convey pro-environmental, pro-ecological, and sustainable behaviors, since it has been used across eco-psychology, conservation biology, and sustainability research (Soga & Gaston, 2024). Pro-environmental behaviors (PEBs) is a common phrase in the literature but emerges from environmental psychology, and it may connote environmentalism which can carry political baggage (Thomashow, 1995; Trinh, 2021). Using the phrase pro-nature behaviors better aligns

with my transdisciplinary dissertation that brings together constructs from different fields of study.

Transformative experience (TE) is a framework that comes from educational psychology and describes students' changes in perceived usefulness of course concepts through reflections on those concepts' everyday uses and value. The process leading to these sorts of transformations is thought to include learners being motivated to apply course concepts in their everyday lives, changing their perceptions of those everyday experiences due to their use of the concepts, and increasing how they now value concepts for their usefulness in their lives (Heddy et al., 2017; Pugh, 2011, 2020).

Teaching for Transformative Experiences in Science (TTES) gives practical teaching methods for increasing the likelihood of students having a TE (Pugh et al., 2010a). Included in this setup are instructors modeling the three components of TE with personal examples (i.e., of motivated use, changes perception, and experiential value), scaffolding student opportunities to practice sharing their transformative experiences paired with feedback, and framing course concepts around experiential value (Pugh, 2020).

Transformative learning (TL) emerged from the field of adult and higher education in the late 1970s (Mezirow, 1978) and describes adult learners' experiences through which their previously unexplored perspectives, worldviews, and identities are massively changed to better encompass new and diverse experiences and observations. The processes identified that might lead to these sorts of transformations include having disorienting or awe-inspiring experiences, reflecting on one's previously unexplored assumptions through critical rational or extra-rational reflection, critical dialogue about those reflections, and opportunities to act out one's new worldview or identity (Cranton, 2016).

Roadmap for the Dissertation

In chapter two of this dissertation, the theoretical underpinnings that led to transformative experience, transformative learning, and ecological identity are described to provide foundations to understand each concept. With these underpinnings in place, a review of literature to summarize and exemplify the research and applications of each of the concepts is addressed. In particular, the focus of this literature review will be in higher education settings.

After the background of those theoretical foundations and extant literature, I introduce and give details about my research methods in chapter three, including my research questions and analyses that were planned to address them. Chapter four describes the results of my quantitative and qualitative analyses to help provide answers to my research questions. My fifth chapter discusses more specifically how the results provide insights into answers to the research questions, implications of those findings, limitations of my study, suggestions for future research, and a general conclusion.

Chapter 2: Prior Literature

In first part of chapter 2, I give the underpinnings of the three main constructs being intertwined for this study. I cover identity theory first, explaining how ecological identity is a type of *person identity* using a psychosocial view of the self. Transformative learning theory is then introduced from the adult education realm before laying out the history and development of transformative experience. With these theoretical backgrounds in place, the second part of this chapter summarizes the research and current work on these three constructs, especially in higher education and partly in other formal educational settings.

Theoretical Underpinnings

Identifying Oneself

Since ecological identity has been suggested as a strong predictor of long-term, pro-nature behaviors, an understanding of identity theory is an important first step in enhancing education for sustainability and the environment. Identity theory has been studied across philosophy, sociology, psychology, and elsewhere, so I describe the pieces of the theory that led to ecological identity as applied in this dissertation research.

Rather than being a singular and simple concept, defining exactly what identity is, how it develops, and how it changes over time is much more complex. In its broadest sense, our identity is our self-concept – who we see ourselves as being. Complexity arises when we recognize that our multiple identities are formed and can shuffle across human developmental stages (Erikson, 1968) and between different contexts – dependent on the surrounding people, situational characteristics, cultural norms, and how we interpret who others think we are. While identification with some group, social category, or role is an internal psychological process, our identities encompass self-identifications across multiple groups, how we differentiate ourselves

from outgroups, and our perceptions of how others define and see us across multiple identities – all happening dynamically (Burke & Stets, 2023). Both internal micro and external micro, meso, and macro processes influence identity formation and changes (Stets, 2021). This portion of the dissertation highlights psychological and sociological contributions to identity theory and social identity theory, which overlap to inform the construct of ecological identity that I sought to examine in a science education context.

History of Identity Theory. George Herbert Mead's contributions to identity theory (1934) were the applications of symbolic interactionism, emphasizing the role of individuals' social interactions and the symbolic meanings they give to objects and actions as they continually shape and reshape their self-concept. Mead, a social psychologist, claimed that children develop a sense of self through taking on the perspectives of others through socialization as they internalize cultural practices, societal norms, and values. The implication is that identity develops by adulthood, but that various aspects of identity may play out in different contexts and can continue to be molded by those contexts and experiences. The idea of multiple identities grew out of this line of thought. We hold multiple identities at one time that exist in a hierarchy and can be activated depending on the situation. Modern research assumes individuals' multiple identities lie on some continuum from central to peripheral in overall self-concept and are activated differentially by context to validate them (Burke & Stets, 2023).

Erik Erikson (1968) also took a psychosocial view of identity development but focused on identity crises that we endure at eight developmental stages across our lifespans. In Erikson's explanation, like in Mead's, social interactions play a significant role in identity, but unlike Mead, Erikson gave more weight to internal psychological conflict resolution and innate biological characteristics. Each of Erikson's stages involves an exploration and grappling with

questions of personal identity, values, and purpose, and the results of each struggle could be a more stable central identity or one that remains unformed, handicapping subsequent stages. Erikson focused on the identity crisis during youth, which during his research referred to a timespan of 3-5 years around age 18. In contrast, at least in Western societies, a youth culture has now developed that lasts from puberty to the mid to late twenties, and several other factors, like personality and social support, suggest that there is not any one age for completion of identity formation (Eriksson et al., 2020; Meeus et al., 2010). Nonetheless, adolescence continues to be researched as an essential stage for the development of a more stable, central identity at some point in later adulthood (Meeus et al., 2010).

To elaborate on Erikson's view of identity formation, James Marcia (1966), suggested that identity crises result in exploration of identity alternatives and decisions about a commitment to engaging in activities of the previous or new identity. The interplay between stable and confronted identities along with the temporal components of exploration and commitment result in one of four statuses of the individual: *Diffusion* where there has been no exploration nor commitment; *moratorium* where exploration is active, and no commitment has been made; *foreclosure* where there is commitment without exploration; and *achievement* where a commitment has been made after exploration. From here, research diverged into the processes and intensity of the activities underlying Marcia's levels (Crocetti, 2017; Karkouti, 2014; Waterman, 1982), leading to a conclusion from a systematic review across domains that claims identity formation can be measured by looking at each identity's distinctiveness, coherence across life domains, and continuity as a self over time (van Doeselaar et al., 2018).

A Psychosocial View of Identity. According to social identity theory, our social group and social category identities come with our recognition of being part of in-groups of some social

circles and out-groups of others (Hogg & Abrams, 1988). Along with that in-group membership come the worldviews, values, beliefs, and behaviors that are normed within that group embedded in a cultural context. For instance, what it means to be a cowgirl in Oklahoma may be slightly different than the characteristics and meanings of being a cowgirl in Argentina. Though we are born into certain social categories (ethnicities, nationalities, families), we still must recognize and test those memberships at some point in development to integrate and order them in our overall self-concept. Also, throughout life, we are evaluating memberships in other social groups (friend groups, career, special interest groups) through validating or invalidating meanings underlying each identity as we activate them across different contexts. We interpret the reactions of others to our identity activations during social interactions to help us form our overall self-concept and identity prioritizations during the same or similar situations. Since everyone is a member of unique combinations of groups, each person has a unique self-concept (Stets & Burke, 2000).

Using the lens of identity theory, this process of self-realization comes from an association with a particular role, group, or category and its related behavioral and attitudinal expectations. Individuals may all be in the same group of interacting individuals but will have different roles that they must negotiate (McCall & Simmons, 1978). The emphasis of research in these interactions is on interconnected uniquenesses between in-group members. Stets and Burke (2000) summarize this overlap: “Although it is important to examine how a person categorizes herself or himself as a member of a group [self-identification], it is also important to observe the role that the person enacts while a member of the group” (p. 228). Individuals’ reflections on their place in a structured society is what helps solidify identities that are more central to the individual’s self-concept and may be enacted more often and across more contexts. While self-

identification is important, social identity theory expands our sense of self by recognizing the importance of cultural meanings given to different identities and of our ongoing attempts at verifying our identities based on our perceptions of others' acceptances of our identities across a variety of contexts.

Identity researchers recognized a limit to the theory, because neither role (e.g., student, researcher, daughter), social group (e.g., sorority, Central High School Pirates basketball player), nor social category (e.g., Hispanic, female, middle class) identities describe a type of identity that transcends any particular role or group. *Person identities* emerged as a type of identity, integrated with both social and psychological identity theories (Brewer, 1991; Stets, 1995), that is tied to the individual rather than roles or groups. Person identities operate across situations, so are more central to an individual's self-concept. Educators must keep in mind that each of their students are entering learning environments with different sets of identities, such as "first-generation student" or "nonscientist," but they are also bringing their person identities. Depending on those identities, and their placements in each students' identity hierarchies, they will have different interests or motivations to learn different topics. For instance, a student who sees themself as "outdoorsy" might verify that identity by trying to learn more and answering questions in the ecology unit of a biology course, while someone who sees themself as an "urbanite" might seek to be seen by others as less interested in ecological topics to verify that identity. People, including students, tend to work to avoid identity disruptions or nonverifications, though it is through this discomfort or distress that identities can change (Burke & Stets, 2023; Illeris, 2014).

The Fluidity and Stability of Identities. Taking this theoretical background on identity and how it forms, questions may arise about mechanisms by which stable identities come to change. Classifying identities as either formed or changing is a false dichotomy, as identities are

better considered on a continuum and are always shifting to some extent (Kaplan & Garner, 2017). “Identity change is...ubiquitous. An identity standard is not fixed and static. It is the (slowly) varying output of one or more identities at the next level up in the control hierarchy of identities” (Burke & Stets, 2023, p. 215). Nonetheless, identity theory posits that humans work towards stability and the avoidance of the distress that comes from identity nonverification (Burke & Stets, 2023).

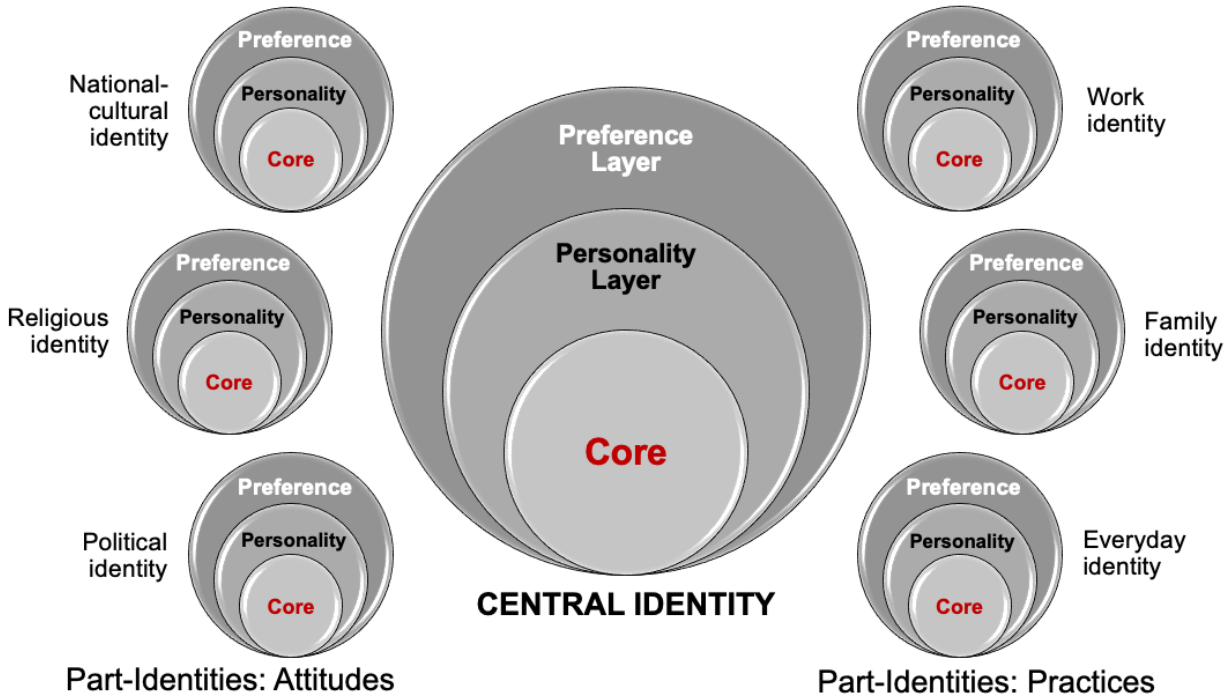
Adults tend to have more stable identities than adolescents, and this may be due to larger dispersion of identity meanings in younger individuals which become more focused with age as those identities are stabilized through verification in more, and more diverse, social settings (Crocetti, 2017; Meeus et al., 2010; Waterman, 1982). Shifting identities in youth may also be due to increased incidence of extrinsic changes (e.g., family roles, student/worker status, societal expectations, relationship statuses) during that life stage. In adults, larger shifts in identity meaning structures and hierarchies still happen but are more likely to happen gradually (Stets, 2021). Still, research has shown that quicker, longer-term shifts can occur over weeks or months, especially with epochal extrinsic stimuli like a sudden change of job, new or ending relationship, natural catastrophe, or winning the lottery (Burke & Stets, 2023).

As suggested by Stets and Burke (2000), Illeris (2014) integrated these psychosocial identity theories into a model to better understand the self. In Illeris’ work, the goal is to understand the role of education in promoting transformative learning towards identity shifts. In his model, the self-concept is comprised of a central (person) identity along with more peripheral part-identities. He classifies these part-identities as being either of attitude (national-cultural, religious, and political identities) or of practice (work, student, and family identities) - what others have named, respectively, group/category- and role-based identities (Bruke & Stets, 2023).

He envisions each of these identities as composed of an inner core, a middle personality layer, and an outer preference layer (Figure 1). The core identity begins to develop in infancy and childhood but only reaches permanence at the end of youth, after which time it is less changeable, in this model. The middle, personality layer includes the individual's values, attitudes, convictions, and social elements (e.g., manners, conventions, habits of communication), and is more malleable even after youth. The outer preference layer refers to our behaviors that are more automatic and day-to-day, changing as the environment warrants in both youth and adulthood.

Figure 1

A Model of Person (Central), Role (Practices), and Group (Attitudes) Multiple Identities



Note. Figure modified from Illeris (2014) by the author.

These identities are not stationary, however, either across a lifetime or in different situations throughout an individual's day. The part-identities are not completely separated from the central identity but overlap with it to different extents in different situations. This is another

way to think of the hierarchy or ordering of multiple identities previously discussed. A two-dimensional, static figure (Figure 1) does not fully capture the concept of multiple identities, just as a flat figure of electrons in orbit around an atomic nucleus does not fully convey the probability of electrons appearing in an electron cloud at various distances around a three-dimensional nucleus. Nonetheless, this model gives us a visual representation of how our multiple identities in hierarchical structure could be imagined.

To help assess the dynamism of identity, scholars have suggested that the relative centrality of part-identities can be ascertained through measuring their *prominence*, *commitment*, and *salience* (McCall & Simmons, 1978; Stryker & Serpe, 1994). The prominence of an identity is its subjective importance, relative to other identities of that individual, and is linked to that individual's conceptions of their ideal self (Brenner et al., 2014). Commitment includes both a quantitative and an affective component. Respectively, those are the number of other people with whom an individual interacts that invoke a given identity and the depth or importance of each of those relationships to the individual (Stryker & Serpe, 1994). Finally, salience refers to the likelihood of a given identity being activated in any given context (e.g., both in and out of the classroom; at home and at work). More salient identities are those that the individual is most likely to activate in different situations or those situations the individual is more likely to seek out or even create in which they can act out that identity (Oakes, 1987; Stryker & Serpe, 1994).

A social identity lens says that individuals construct their identities in relation to the natural world most directly through social interactions and cultural influences. In the context of my research, this informs us that people develop their understanding of environmental issues, attitudes towards nature, and behaviors related to ecosystems based on societal norms, family upbringing, peer interactions, and broader cultural values, each of which can change at different

points in a person's life or across contexts. Stronger nature-based identities, from a Meadian view (Mead, 1934), would be constructed and communicated through discourse, narratives, and group meanings attached to others who uphold norms and behaviors that are more environmentally sustainable. Both through association with groups known as being pro-nature, and through dissociation from groups that are anti-nature, individuals move their ecological identities to be more central in their overall self-concept.

Considering identity theory, especially through an Eriksonian lens (Erikson, 1968), one of the potential identity crisis topics that an individual could explore in their youth is their relationship with nature, their environmental values, and their sense of responsibility towards the natural world and others. That is, they could be asking: What role will I play in reversing climate challenges? Do I want to be known as a champion of environmental justice issues as I reach adulthood? How much do I want to associate with others who are pro-nature? Do I believe my sustainable living choices will be worthwhile or futile? Individuals' resolutions to this crisis would involve either a centering of their ecological identity – them seeing themselves as part of their ecosystem becoming a proportionately larger part of their self-concept through ongoing validation with others – or a separation or shift of their ecological identity as more distal to their central identity. This centrality of their ecological identity could be explored by assessing its prominence, commitment, and salience across different contexts (e.g., school, family, friend groups). My literature review section will further describe ecological identity as a type of person identity to consider in educational settings.

Learning that Transforms

Students in higher education may be traditionally aged students who are in the middle of forming their identities, perspectives, and worldviews, but they also could be young adults or

adults who have more stable identities. For this reason, understanding the educational components that lead to transformation of our learners' assumptions, mindsets, mental schemas, and identities is important. Theories of transformative education, particularly transformative learning, are described next in service to our understanding of how post-secondary education may shift students' ecological identities.

Development of Transformative Learning Theory. Transformative learning (TL) theory was conceptualized and introduced by Jack Mezirow in 1978 to describe his observations of adults undergoing profound transformations that led to new self-concepts, ways of being, and actions (Eschenbacher & Levine, 2022; Mezirow, 1978). The theory grew out of Mezirow's own research, most directly on 83 women reentering college programs as adults, with strong influence by Dewey and his contemporaries Kuhn (1962), Freire (1970), and Habermas (1971) in their descriptions of pragmatism, learning paradigms, and of emancipatory social movements. TL theory has continued to evolve in concept and definition, even being considered by some a metatheory that encapsulates several transformative learning theories or interacts with a constellation of other learning theories (Hoggan, 2016b; Kyle & Walvoord, 2024). I summarize TL as a theoretical framework, including its evolution, critiques, and ties to this dissertation study.

John Dewey was one of the major contributors to the early 20th century philosophy of pragmatism which had a pivotal influence on Mezirow and is a foundation of TL theory (Raikou & Thanassis, 2022). Dewey asserted, with other pragmatists, that people make meaning or form their reality not through learning or adopting a universal truth but through putting knowledge into action. People attribute meaning to concepts through the effects and consequences of putting them into action. The result is that meanings can change over time as they are reflected upon,

implemented for problem solving, and tried out in new contexts – they have *warranted assertability* (Dewey, 1933). Another important concept from Dewey is that of *habit* (1922) - stable predispositions built from prior experiences that filter the way we perceive and think about environmental stimuli and problematic situations. Given these definitions, Dewey's, and therefore Mezirow's, work relies on constructivism – the idea that learners construct their own meanings based on experiences (Rennick, 2015).

In describing what parts of learners are changing during different learning experiences, Mezirow referred to various structures as his theory evolved: Frames of reference, meaning perspectives, meaning schemes, habits of mind, and points of view (Mezirow, 1985). His understanding of these different structures that could transform grew out of Dewey's descriptions of habits (1922) and Kuhn's (1962) descriptions of paradigms. Paradigms are widely recognized fields of study that provide practitioners with an accepted way to see and solve problems in that field. Mezirow came to call these paradigms *frames of references*, a type of meaning perspective formed through life experiences, including social influences. These are the lenses through which we intake and interpret new experiences, and they are comprised of two dimensions: Habits of mind and points of view (Raikou & Karalis, 2022). Habits of mind are broad predispositions that allow us to interpret our experiences automatically through a filter, even if distorted, while points of view are clusters of meaning schemes based on expectations, beliefs, attitudes, and feelings. When we have an experience or observe some phenomenon that cannot be integrated into any of our existing meaning schemes, we may either ignore the phenomenon, seek similar observations for verification/nonverification, and/or critically reflect on the unsuitability of our entrenched frames of reference to transform them into new ones that accommodate the discrepant observations (Mezirow, 2000).

Mezirow adapted Habermas' (1971) classification of knowledge as technical, communicative (practical), or emancipatory to help differentiate transformative learning from other types of learning. Instrumental learning is Mezirow's name for the type of learning that leads to technical knowledge - acquisition of knowledge and hard skills. Communicative knowledge, the type derived from social interpretation and groups (e.g., how to be a good leader, building emotional intelligence, codes of commonly accepted behaviors in society), are in place by adulthood and form the basis of the existing assumptions and worldviews that could be examined during TL experiences through dialogue. For this reason, Mezirow called this dialogic learning. Emancipatory knowledge comes from our abilities to be self-determining (aware and critical of self and sociocultural contexts) and self-reflective (aware and critical of our own perceptions and the limitations of social knowledge). Mezirow called this self-reflective learning, and it is the type of transformative knowledge that he elaborated in his theory. He applied Habermas' typology and emphasis on dialogue in civil societies to adult education to examine processes of individual transformation towards societal transformation (Baumgartner, 2012; Eschenbacher & Levine, 2022; Kitchenham, 2008).

Mezirow was also heavily influenced by Paolo Freire, referring to Freire's (1970) explanation of conscientization as synonymous with transformative learning (Mezirow, 1995). Conscientization refers to the process individuals undertake as they become critically aware of their social reality, particularly regarding systems of oppression and domination, then find empowerment to correct that reality. Mezirow borrowed Freire's emphasis on critical reflection and dialogue as crucial steps in leading to emancipated people taking social action against their oppressors. Freire's call for educators to be both co-learners and provocateurs of their students is a direct application to classroom settings to encourage transformative learning. Mezirow even

refers to his process of reading Freire as a sort of disorienting dilemma that led to his shift in perspective about the necessity of critical theory in adult education (Vaikousi, 2020). Just as in his contrast with Habermas, Mezirow expanded on Freire by applying the process of emancipatory change to the classroom and with more of a focus on the individual.

Mezirow characterized TL as occurring in individuals as they underwent 10 steps that altered their frames of references (meaning perspectives; Mezirow, 1981). These steps emphasized rational, critical self-reflection by the individual and both a process and an outcome: 1) experiencing a disorienting dilemma, 2) self-examining, 3) critically assessing internalized assumptions that are part of social norms, 4) recognizing that others have this same disorientation, 5) exploring options for new ways of being, 6) building competence in that new way of being, 7) planning a course of action, 8) integrating new knowledge and skills for that new role, 9) trying out and assessing the new role, 10) rejoining society with that new meaning perspective (adapted from Cranton, 2016).

The Evolution of TL Theory. Changes to Mezirow's early explanations came from Mezirow-centric researchers, Mezirow himself, and critiques of his initial work in an iterative and dialogic process (Kitchenham, 2008; Kokkos, 2020). Areas of exploration included what transforms in an individual through this process, defining disorienting dilemmas as happening either gradually or through epochal events (Mezirow, 1985, 2000), elaborating on the types of critical self-reflection required to promote TL, and expanding on the importance of rational dialogue across many of his proposed phases (Schapiro et al., 2012). For instance, he further defined the impacts of learning on meaning schemes within each of the three learning types (instrumental, dialogic, and self-reflective), saying that adults can learn within their existing meaning schemes (expanding or revising them), add new meaning schemes to their existing

frames of reference, or create new frames of reference through encountering anomalies that don't fit, the latter one being when TL occurs (Kitchenham, 2008).

Mezirow further elucidated what he meant by self-examination and critical assessments in his steps towards transformative learning. Critical self-reflection, as differentiated from critical thinking, is tied to critical theory (Freire, 1970), and Mezirow defined levels of reflection as assessment of one's content, processes, and premises used to assign meaning to experiences (Mezirow, 1991). Content reflections ask the "What" questions, process reflections ask the "How" questions, and premise reflections ask the "Why" questions (Cranton, 2016). Only by reflecting at the premise level can we hope to transform our meaning perspectives. To highlight the importance of dialogue throughout the TL process, emphasizing that his theory is of individual transformation but in social contexts, Mezirow again borrowed from Habermas (Eschenbacher & Levine, 2022). Mezirow called for discursive learning in places where power dynamics between participants are recognized and mitigated, information is available to all, trust is built, and the topics of discussion are the reified meaning perspectives that are being reflected upon (Mezirow, 1991). Only in this discourse can previously unexplored perspectives on ecological identity, or any other topic, be tested and have the greater possibility of being acted upon.

Critiques and research from other scholars led, and is leading, to a more inclusive understanding of TL that incorporates affective, not just rational-reflective, ways of knowing (Taylor & Marienau, 2022), integration of those extrarational components as potential reflections during the steps of TL (Dirkx et al., 2006), an acknowledgment that transformation can be collective and not just individual (Buechner et al., 2020), and even a reconceptualization of TL as shifts in identity (Illeris, 2014). Interestingly, many of the reemphases in Mezirow's original

conception of TL came from researchers' reexamination of the work of those theorists who had originally influenced him (Dewey, Freire, Habermas, and Kuhn). This iterative process of Mezirow publishing revised thoughts of TL, inviting critique (dialogue), reexamining literature and data, and revising terminology or concepts of TL have allowed the theory to continue to grow as an area of inquiry.

Valuing Experiences Differently

In contrast to TL, a student is considered to have had a transformative experience (TE) when they were intrinsically motivated to use a class concept outside of class, their perception of the experience is changed because of that, and they now value that class concept differently because of seeing its everyday relevance (Pugh, 2011). TE is a composite of several constructs that are often researched separately in educational psychology, and it is based on the theories of constructivism, social-cognitivism, self-determination theory, and expectancy-value theory (Pugh, 2011, 2020). TE can best be compared with TL by reviewing Dewey's pragmatism and aesthetic view of education.

Underpinnings of Transformative Experience. John Dewey claimed the goal of education should be enrichment of the lives of students, not just by helping them learn and understand their school subjects, but by guiding them to see beauty around them and value their education for how it helps them experience the world in new ways (Dewey, 1934). His views of learning evolved as he continued to write, dialogue, and work in his field (Wong et al., 2001), much like Mezirow's. Dewey is often cited in science education, which makes it fitting since TE was first employed in science classrooms. This is another interesting parallel with Mezirow, whose TL theory was influenced by Kuhn's work in the sciences.

Experiences were important in Dewey's work, and he differentiated *everyday experiences*

from *an experience* in education that is "imbued with anticipation, development, and unity, [that] also becomes an act of thinking and meaning" (Wong et al., 2001, p. 320). Dewey's descriptions of this type of experience seems to describe what has now been called *flow* in educational psychology work on intrinsic motivation (Csikszentmihalyi, 1990). Flow is a learner's state of complete absorption in a learning task characterized by intense focus and losing track of time. Pugh (2011) emphasized that for Dewey, one key characteristic of these types of educative experiences is anticipation. Anticipation of choice, discovery, impact, and answers can drive learner engagement and have long-lasting impacts.

Dewey described the source of that anticipation as *ideas*, which are characterized by creativity and connection to what is being learned, having forward motion, being imbued with ownership, and inspiring action (Wong et al., 2001). Ideas become concepts if they travel to an ending point, but at that point, they risk becoming less about *an experience* to later learners. In our learning environments, we must find ways to facilitate students' reanimation of those concepts into ideas. This can be done through connecting learners back to the historical and personal contexts of the initial idea formation, giving descriptions of how the concept became an idea for us and influenced our perceptions, and by leaving open the way for their own ideation through both cognitive and affective means (ibid.). Wong et al. (2001) say there is a connection between ideas and identity: "For Dewey, we believe, identity also included one's relationship to or participation with the world (natural and social) as made possible by ideas" (p. 335).

If, as Dewey suggests, ideas are the key to making a learning experience *an experience* that moves, what is the fuel that propels that vehicle? Students' motivation, and more particularly, the type of intrinsic motivation known as *interest* is a candidate. Personal interests are those that show up in individuals consistently across different situations and reside within the

individual, while situational interests are those that can be triggered or maintained by external stimuli (Hidi & Renninger, 2006; Ormrod, 2020). The most beneficial types of interest, because they keep learners engaged in a topic longer so that they cognitively or extrarationally process their experience, are personal interest and maintained situational interest. Attention-grabbing situational interest, that comes from a showy demonstration, surprising fact, or loud noise might initially pique students' interest, but may not lead to the sustained engagement necessary for impactful learning (Barron, 2006).

Instructors can use strategies to tap into their students' personal interests and longer-lasting situational interest to engage them in transformative experience, transformative learning reflections, and/or identity-shifting activities. These include introducing topics in relation to people and culture, nature, entities in popular media, and those with charged emotional content (Ormrod, 2020). There can even be a reciprocal relationship where a student gaining knowledge and skills in a certain area increases their sense of self-efficacy, further driving their interest, which if perpetuated, can be a key component of learners' identities (Barron, 2006; Hidi & Renninger, 2006; Ormrod, 2020). Pugh (2020) outlines more specific strategies, growing directly out of Deweyan pragmatism towards encouraging students' TE.

Beyond incorporating research on interest and Dewey's aesthetics (Pugh et al., 2015), TE also considers the learning sciences research on motivation, transfer, value, goal theory, and conceptual change. The purpose of research on TE is not to deeply explore any one of these areas, but to take what has been shown to be useful in each of them for student learning, and to create a framework to implement and put into practice (Pugh, 2011). In this sense, it fits with Dewey's contributions to the philosophy of pragmatism.

Constructivism is a paradigm that proposes that we acquire new knowledge and beliefs

by connecting new experiences to our existing knowledge and beliefs. The learner must actively construct this new knowledge, so acquiring it depends on how that individual perceives and interprets the new material and how they make connections to prior knowledge. As these connections are repeated, our brains form schemes, or patterns of thoughts and actions in response to similar experiences (Ormrod, 2020). In contrast, information processing theory explains that our learning as an absorption of knowledge that we are given from some expert source. TE is built on the constructivist paradigm, like TL, but TE aims to find ways to help learners reflect on and connect new knowledge to existing and everyday experiences.

This construction of knowledge is carried out both individually and socially and relies on cognitive processing. Because constructivism has been explored individually and in group learning, social constructivism overlaps with another basis of TE – social cognitivism. We learn and construct our own meanings through both individual reflection and through watching and dialoguing with others (Ormrod, 2020). TE incorporates social cognitivism through its emphasis on learners discussing their experiences with peers and receiving feedback from the instructor.

Research on expectancy-value theory (EVT) also helped undergird TE's development. EVT says that individuals' motivation to learn can be explained by both their belief in how well they can do on a learning task and on the extent to which they value the activity (Wigfield & Eccles, 2000). The learner's expectancies include their perceptions about their own competence to engage in the activity, how likely they believe they are to succeed at the task, and their beliefs that their specific actions will lead to a given outcome. In other words, their expectancies are related to their self-efficacy. To understand learners' values, researchers focus on attainment value (importance of doing well on the task), intrinsic value (enjoyment of the task), utility value (the task's direct connection to their goals), and their perceived cost of performing the task (both

from effort and emotional cost). More recent work has pointed out the importance of context on these factors, expanding the theory to Situated EVT (SEVT; Eccles & Wigfield, 2020).

The fourth main theoretical foundation of TE is self-determination theory (SDT; Ryan & Deci, 2017). This theory focuses on the importance of intrinsic versus extrinsic motivation for deeper learning and longer-lasting engagement. SDT claims that when humans have optimal levels of autonomy (choice), competence (perception that they can be successful), and relatedness (bonds to others), intrinsic motivation is most likely, though extrinsic motivation can also have a vital role depending on instructor goals. Autonomy-supportive environments encourage learner choice, learner initiative, are learner-centered, provide positive feedback about successes, and help individuals self-diagnose their weaknesses while providing support and structure. Work by La Guardia (2009) shows that this sort of social support in autonomy-enhanced environments is ideal for children and adolescents' exploration and commitment to new identities.

The Practice of Transformative Experience. TE is structured to promote intrinsic motivation and positive emotion by tying content to the learner's everyday life to make the content more relevant, so that they are motivated to learn, remember, and use it (Goldman et al., 2017). TE gives students practice at transfer – applying course concepts to something outside the classroom – and helps them learn it more thoroughly, so that they will find applying it to other contexts easier (Haskell, 2001). Value is built in by asking students to reflect on how using the concept in their everyday lives changes the value of that experience for them, and in doing so, may build importance, utility, and interest in that concept while lowering the cost of understanding and using it (Wigfield & Eccles, 2000). By including discussions of each student's TE into courses, social goals can be a driver to encourage academic achievement (Dompnier et

al., 2015). Finally, TE incorporates conceptual change research (Posner et al., 1982) by providing opportunities for students to learn or relearn concepts in meaningful contexts and elaborate on that learning during discussions or reflections.

The relationship between ecological identity, TL, and TE has not been explored, but based on their theoretical underpinnings, a relationship can be hypothesized. Because Illeris (2014) has defined shifts in identity as a potential definition of TL, students' transformative learning in the domain of environmental education should be positively correlated with their shifts in ecological identity. Since both TL and identity shifts may be difficult to accomplish in adulthood, employing TE in a college classroom environment could serve to build students' interest and value to do TL and identity work towards developing a more centralized ecological identity. That is, TE may act as a mediator to enhance students' TL as defined by identity shifts. The literature review in the next section builds on this argument by exploring previous research on each of these three constructs.

Prior Research on the Three Constructs

The goal of this section is to summarize, synthesize, and give examples of the research and applications of three constructs that are underpinned by the theoretical examination in the previous section. Ecological identity, a psychosocial construct, transformative learning, an adult learning theory, and transformative experience, a composite of educational psychology concepts, will be further described in the context of higher education. This literature review will help expose gaps in those three areas of study and existing or potential areas of overlap. This co-examination leads to my research questions towards education for sustainability in higher education to potentially mitigate the climate crises we are facing as a society.

Higher education is an important context through which these concepts can be viewed

since, unlike in informal education, there are usually longer spans of time and more interactions during which to implement interventions and record results with the same groups of learners (Schwalbe & Mason-Schrock, 1996), and unlike in K–12 education, higher education students may be more practiced at critical reflection and traditional college students are at the cusp of more stable adult identity. Research on what sort of educational interventions to employ in college courses to reach the goal of increased pro-nature behaviors has been much studied, though never in the overlap of TL, TE, and ecological identity. This is a major gap in the research.

Some important research has focused on increasing students' understanding of ecology and sustainability concepts, and changes in this content knowledge can be measured with traditional content assessments or broader assessments of ecoliteracy (Cheruvelil & Ye, 2012; McBride et al., 2013; Okur-Berberoğlu, 2018). Increases in ecoliteracy are a crucial step but are insufficient to elicit the lasting behavioral changes necessary to tackle environmental challenges (McGuire, 2015). Rudolph (2024) even claims that the idea of *science literacy* should be scrapped altogether due to its vague description and lack of correlation to reaching concrete science education goals. Alternatively, pedagogies that promote students' increased connectedness to nature may be important, as this construct adds affective components to the cognitive growth previously described and is correlated with short-term, pro-nature intentions or behavioral shifts (Frantz & Mayer, 2014; Hinds & Sparks, 2008; Nisbet et al., 2009; Otto et al., 2021; Richardson et al., 2020). While these connection-to-nature measures are correlated with attitudes, beliefs, or values, which are tied to individuals' meaning schemes (Clayton et al., 2021), they are separate constructs. Attitudes drive behaviors only in certain situations or in the near-term – that is, they are contextual so less stable across social situations, cultures, and over

time (Hayes-Conroy & Vanderbeck, 2005; Kahn, 1999; McGuire, 2015; Stets & Biga, 2003).

A more stable construct to explore towards impacting pro-nature behaviors is ecological identity. This literature review explores higher education as a crucial learning environment for which to design transformative educational experiences to maximize the potential for students' ecological identity formation and shifts which lead to longer lasting pro-nature behaviors to solve the wicked problem of sustainability (Goodwin, 2016; Lönngren & van Poeck, 2020; Walton & Jones, 2018).

Ecological Identity

To understand ecological identity, it first must be contrasted with science identity, which has a strong base of research, and with environmental identity. Through these comparisons and references back to psychosocial identity theory described earlier, the reader will come to understand ecological identity and its power to predict pro-nature behaviors and be influenced by both transformative experience and transformative learning.

Science and STEM identity have been studied across age groups and are defined as the aspect of the self that relates to science or STEM, with recognition that they can be intersectional with gender, race, ethnicity, or other identities (Carlone & Johnson, 2007; Hazari et al., 2013). An important distinction often missing in the literature is that between a professional identity (seeing oneself as a scientist or STEM professional now or in the future) and seeing oneself as a scientifically literate person. A non-science major will likely never see themselves as a scientist or future scientist as a role, person, or group identity, but they may incorporate into their central identity being curious about nature, identifying as a data-informed citizen, or being educated about scientific topics like cancer, gene therapy, evolution, or climate change.

Using the psychosocial theory of identity as presented in Figure 1, we could conceive of

science identity's location for science majors in the central core, central personality, or part-identity work core upon attainment of their academic degrees. We would aim for these majors to see themselves as scientists as their partial career-selves or even in their central selves. For nonmajors though, we would instead set up learning experiences with the goal of students incorporating higher science self-esteem into their political or everyday part-identities. Vandegrift et al. (2020) explain the importance of including science literacy identity as a goal for nonmajors: "Our focus on student science literacy self-belief is particularly important in general education courses designed to empower students in scientific thinking, especially when these courses might be the last formal science instruction students received" (p. 25).

Science identities are role-based (linked to a student's major, field of study, and future career) (Stets & Biga, 2003), whereas nature identities in the literature are conceived of as person identities. The latter refers to students' incorporation of nature into their self-concept rather than their identities as environmentalists or ecologists. Beyond just an identification with the natural environment, nature-based identities are viewed through a psychosocial lens because they incorporate cultural and social aspects into the overall self-concept through verification across diverse contexts.

Nature-based identities have been given various names, with nuanced differences between them, but overall provide a way to predict people's behaviors towards the natural environment, such that someone with a more central nature identity is more likely to act positively toward the environment to verify that identity through self- and other-appraisals (Burke & Stets, 2023; Clayton & Opotow, 2003; Stets & Biga, 2003). With behavioral change as the goal then, McGuire (2015) makes a compelling argument that "self-identities are a psychological construct with tremendous potential from the perspective of environmental

education," because they are more predictive than previously used knowledge, literacy, or attitude measures.

Environmental identity is one type of nature-based identity, though use of the term "environment" may be misleading as it could convey the built or social environment, not just the natural environment; work on it uses a more social than psychosocial identity theory lenses; and learners who have a negative view of environmentalism may react negatively to it, leading to a resistance to learning ecological concepts (Clayton & Opotow, 2003; Thomashow, 1995; Trinh, 2021). *Ecological identity,* in contrast, is a phrase that has been reintroduced from Thomashow (1995) but redefined with psychosocial identity theory (Walton & Jones, 2018). This construct has the theoretical basis to predict longer-term pro-nature behaviors compared to ecological literacy or improved attitudes about the environment (Goodwin, 2016; Kunchamboo et al., 2021; Marković et al., 2024; McGuire, 2015; Stets & Biga, 2003). Ecological identity is considered an overarching concept that encompasses both deep connection to nature and the more socially focused environmental identity construct (Clayton et al., 2021; Walton & Jones, 2018).

While research on environmental identity has begun to include the importance of both strength and salience in predicting pro-environmental behaviors (Rahmani et al., 2022), the construct of ecological identity has been built with additional subcomponents to increase predictive power. Ecological identity refers to how individuals see themselves as embedded in ecosystems, and Walton and Jones (2018) describe it as "the extent and ways by which an individual views [themself] as being a part of an integrated social and biophysical (i.e., ecological) system characterized by mutually beneficial processes and nested webs of relationships" (p. 666). In developing their Ecological Identity Scale (EIS, ibid.), they included the supported sub-components of *sameness* (connection to nature and pro-nature roles/others),

differentiation (separation from anti-nature roles/others), and *centrality* (identity as central versus a role-based identity as determined by its prominence, commitment, and salience). The inclusion of differentiation, in the social aspect, and centrality, as a person identity, provides more contrast between ecological identity and the environmental identity construct (ibid.), though research from both could help inform the design of interventions to impact learners' nature-based identities towards pro-nature behaviors.

Developing a Nature Identity. As described in the theoretical background section, identity theorists explored important aspects of self-development prior to language acquisition, continued formation and development once verbal, important steps to begin stabilizing central/person identities in adolescence, and finally more stabilized, though still fluid ordering of, identities in adulthood (Erikson, 1968; Marcia, 1966; Mead, 1934; Stern, 1985). For nature-based identities, these same stages are also important. Marković et al. (2024) summarize that ecological identity is formed through repeated positive nature experiences, developing ecological knowledge, influential role models, recognition of the self as part of nature, and cultural-historical factors.

Prior to formal education, norms, socialization, and cultural values towards nature begin to develop in family or caregiver systems through conversations, behaviors (including time in nature), and informal education (e.g., zoo visits, assisting in the garden, family pets). Johnson et al. (2004) pointed out variations in environmental concern and behavior across ethnic groups in the United States, indigenous people's connectedness to nature has been tied to their wellbeing (Keaulana et al., 2021), and Estrada et al. (2024) recently contrasted ecological identity between different ancestral groups in Southern Patagonia. An extensive qualitative dissertation by Jardine (2016) of 17 adults of diverse backgrounds similarly showed "that early ways of interpreting and

relating to the natural world can be recognized in patterns of interactions [with] the natural world throughout one's entire lives" (p. 148). These studies reiterate cultural, and very early, influences on nature-based identities.

Further socialization and cultural norms are adopted as social influences broaden through formal education and media, especially through teachers, older students, and peers as role models (Goshylyk, 2023; McGuire, 2015; Prévot et al., 2018). The impacts of educational environments on student identities are of special interest because those settings are influenced by curricular choices, instructor development, policies, and standards (e.g., K–12 state standards, accreditation). Chawla and Cushing (2007) described the importance of teachers' displays of enthusiasm towards pro-environmental behavior for developing environmental identity in children ages five to seven. After that age, the social environment and peers become increasingly important in identity development, including ecological identity, throughout adolescence (Redman & Redman, 2014). The characteristics of educational activities and contexts that affect students' ecological identities must be understood to guide curricula (Lankenau, 2018).

The most positive influences on students' nature-based identities come from environmental education activities that are experiential (e.g., adopting school garden plots, maintaining worm composting bins), integrated across the curriculum laterally (across subjects) and vertically (over time), promote the display of positive affect by role models, give space for reflection on individual but also collective influence on ecosystems, and are collaborative and community-based (Chawla & Cushing, 2007; Kosta et al., 2022; McGuire, 2015; Moroye & Ingman, 2013; Scott, 2023; Trinh, 2021). Simms and Shanahan (2024) empirically demonstrated with a group of 35, 6th graders in Canada that activities that increased students' environmental awareness, social action with peers, affective response, personal meaning, reflections on

ecological topics and their own behaviors, and agency were important to environmental identity development. Williams and Chawla (2016) specifically showed the importance of intensive outdoor experiences by assessing the impacts of childhood outdoor environmental education on adults' environmental identities 5 to 40 years after participation. In other words, there are social, affective, and cognitive components to the formation of ecological identities that all must be considered during educational activities.

The role of instructors in higher education settings to influence nature-based identities is more complex than with younger students. The age range of traditional undergraduate students in the United States is 18 to 24 years old, which falls within the current zone of continued identity formation – not yet fully stabilized, as the period of "youth" in the United States now may last to the mid-to-late twenties (Illeris, 2014). Depending on the cultural backgrounds and experiences individuals have had, they may be more or less developed in their overall self-concept and in their ecological identity. Illeris (ibid.) makes the point that while identity development and identity transformation are two different processes, "educational efforts at this age [must] aim at identity forms that at one and the same time are relatively stable and open to transformations" (p. 88). Hayes-Conroy and Vanderbeck (2005) came to a similar conclusion in their qualitative study of ecological identity work in undergraduate students in the northeastern U.S. They concluded that some students undertake conformative identity work (validation opportunities) "while also in some ways attempting to redefine these very boundaries of ecological identity (which we refer to as critical identity work)" (ibid., p. 310).

Additional complexity is added when considering that undergraduate student enrollment in the United States is comprised of both traditionally and non-traditionally aged students. The U.S. Department of Education (2024) reported that in fall 2022, 22.6% of enrolled

undergraduates were ages 25 and older, so would be expected to have more stabilized identities, including ecological identities. This means that teaching strategies for ecology and environmental sciences would need to include both those that encourage student exploration of their ecological identities in addition to more transformative teaching methods that include disorientation, critical reflection, and dialogue to give opportunities for students to transform the more stable makeup of their identity hierarchies.

A handful of studies have shown that college students' nature-based identities, or a related construct of nature connectedness, can be impacted through curricular or co-curricular modification. Lankenau (2018) showed that an introductory ecology nonmajors course with nature-identity and -connectedness foci significantly increased students' identification and connectedness to nature. "Traditional exams and papers are eschewed in favor of more reflective assignments [e.g., outdoor reflective activities], such as a weekly journal and an ecological identity project" (p. 233). An 18-day wilderness expedition by undergraduates in Alaska uncovered the importance of guided reflection (interviews) and of considering both personal and social identity (Standard, 2023). And Watson et al. (2015) found positive correlations between undergraduates living in green residence halls, peer modeling behaviors, and environmentally responsible behaviors.

The Multitude of Nature Identities. So far in this dissertation, various nature-based identities have been used synonymously, so this section begins to add contrast to them. Empirical research on nature-based identity is difficult to summarize or synthesize, because pockets of it can be found in different disciplines (environmental education, sociology, philosophy, ecopsychology) where each is using different theoretical bases and instruments for measurement (Wallnoefer & Riefler, 2022; Walton & Jones, 2022). For instance, even though Thomashow

popularized the term ecological identity in 1995 to discuss alignment with environmentalist values (now called environmentalist identity), in 2003 Clayton introduced a measure of environmental identity to measure that same construct. Stets and Biga further refined environment identity in sociology, Hayes-Conroy and Vanderbeck tightened the definition of ecological identity in 2005, and McGuire in 2015 suggested the use of a new Identity-Based Environmental Education model without referring to ecological identity research or historical identity research by Erikson, Mead, or Marcia.

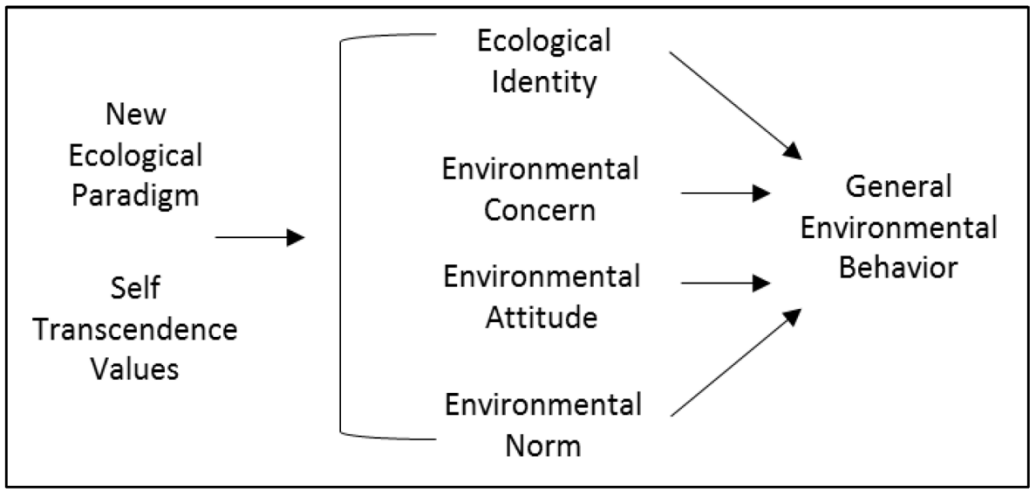
This decentralized research "has limited our ability to generalize findings across studies and accumulate knowledge about the individual and collective factors influencing behaviors aimed at reducing one's...impact on the [natural] environment and others" (Walton & Jones, 2022, p. 1). On a positive note, so many fields independently recommending an identity lens to inform sustainability education solutions bolsters its potential power as a research area and provides important evidence from diverse areas of study. The review below of nature-based identities relies on recent metanalyses and current work from theoretically-rooted studies.

Since the goal of most research in environmental education and nature-based identities is to improve pro-nature behaviors, a summary of that work is reviewed first. In that field, the object of study is often pro-environmental behaviors (PEBs). A study by Walton and Jones (2022) sought to mitigate the confusion and bring the field of study together by summarizing seven major constructs used to study PEBs and by testing six alternative models that included these constructs in proximal or distal formations in relation to behavior. Data collected from 497 undergraduate students from a university in the SE United States on seven different, validated instruments was used to compare alternative models using structural equation modeling. Multiple statistics led to one model (Figure 2) emerging as the best of six alternatives (AIC = 198.6 versus

282.7 for the next lowest AIC value). This study verified that ecological identity plays an important part in PEBs and is a more proximal driver of behavior than environmental values or beliefs.

Figure 2

Best Approximating Model of Seven Identity – Pro-Environmental Behavior Constructs



Note. From Walton and Jones (2022).

A recent metanalysis was conducted on the identity-PEB literature and can further inform the study of ecological identity. Udall et al. (2021) searched for research papers (correlational or experimental) published from 1992–2016 that used identity (individual, "environmental," group, and social) to study PEBs (self-reported, intent to behave, or observational) in any population (student/non-student and from any country). Initial search criteria in four databases led to 5,878 titles/abstracts, filtered down to 474 full text papers on closer review, then to 86 (104 studies) after double-blind review of inclusion criteria. These studies were classified by the search criteria named above, along with identity type (person/individual or group/social measures) for inclusion in a random effects meta-regression model. For both types of identity, there was a positive and significant relationship with PEBs (individual, $n = 58$, $r = .37$, $p < .001$; group, $n = 29$, $r = .27$; p

< .001). Other findings revealed that, overall, identity associated most strongly with group PEBs in the field rather than in the lab and in student rather than non-student samples. Group PEBs and group identities were most strongly associated with self-reported rather than observed PEBs. Overall, this metanalysis indicates that identity is positively associated with PEBs, that both individual and group identity (psychosocial) should be considered in studies, and that results of studies must consider context in their application to other settings (field/lab, student/non-student).

The caveat here, to Walton and Jones' (2022) point about the difficulty of summarizing work in the field, is that this analysis by Udall et al. (2021) was based on studies that used various conceptual bases of identity and PEBs. This metanalysis did not include or classify the studies by demographic characteristics of participants, but in general, college-aged respondents are overrepresented in this type of research (Udall et al., 2021; Wild & Schulze Heuling, 2024), limiting generalizability. Also, the classification of types of identity as either individual or group (person or social identity) is an oversimplification that could overshadow important correlations between person, role, and group/categorical identities with PEBs.

A description and synthesis of four additional identity-PEB studies excluded from Udall et al. (2021), due to publication date or absence from the databases they searched, give a broader picture of the types of research in this field and provide additional findings to consider. These additional studies used the Environmental Identity scale (EID; Clayton, 2003), along with other measures, which align more closely with a social identity lens. They included a mixed methods (Freed, 2015), a qualitative (Simms & Shanahan, 2024 guided by the EID), and two quantitative studies (Clayton et al., 2021; Perez-Ibarra et al., 2020) administered to undergraduates in the U.S. and Mexico (Freed, 2015; Perez-Ibarra et al., 2020), sixth graders in Canada (Simms &

Shanahan, 2024), and high schoolers to adults from five countries (Clayton et al., 2021). In Freed's dissertation, they found positive and significant correlations between environmental identity and PEBs ($n = 299$, $r = .69$, $p < .01$) and between decision-making and recycling ($r = .52$, $p < .01$). During follow up interviews with eight people, frequency of recycling was shown to be unrelated to interviewee identity though, as convenience of recycling and social norms emerged as more important.

Though Simms and Shanahan (2024) studied 35 sixth graders, not undergraduate students, it highlights the increasing study of non-U.S. students, that work is not just done with college students, the continued and current work in identity and PEBs, and that work on fostering environmental identity in children is an area of future research focus. Perez-Ibarra et al. (2020) considered impacts of decision-making and identity formation while also adding a variable of psychological predispositions to sustainability (e.g., appreciation of nature, altruism, affinity to diversity) as a correlate to environmental ID as measured by the EID. They found among 417 students that predispositions were a significant predictor of EID ($\beta = .83$, $p < .05$).

The call in the literature to continue to verify and revise measurements in other cultural contexts was answered by Clayton et al. (2021) to form the rEID as a revision of Clayton's (2003) original EID instrument. This study collected self-report data about environmental behavior to correlate with environmental identity for some of their 1,717 participants. Correlations with behavior ranged from .39 (in Switzerland, university students, $n = 343$) to .57 (in a U.S. MTurk sample, ages 18–75+, $n = 220$). Overall, for these subsamples, EID correlated with behavior at $r = .4$ ($p < .001$). The general findings that environmental identity correlates with behaviors was upheld, even with diverse participants, though additional factors continue to be studied as characteristics that influence, or are influenced by, nature-based identities.

Measuring Ecological Identity. A new instrument was developed to measure nature-based identity, but the paper that described it missed the cutoff for the Udall et al. (2021) inclusion criteria. This new instrument, the Ecological Identity Scale (EIS; Walton & Jones, 2018) attempts to consolidate the disparate constructs in this field based on a more psychosocial identity lens. It was built to incorporate nature-identities from person, role, and group bases, the former being measured by its prominence, salience, and commitment across contexts and the latter by in-group/out-group criteria. Their mixed methods instrument development project included interviewing focus groups of environmental leaders (3) and undergraduates (1) (phase 1), then in phase 2, building survey questions to give to 40 undergraduates for *a priori* power analyses, before administering their instrument, along with other existing scales (ecological worldview and universal values), to 497 undergraduates.

Item and principal components analysis led Walton and Jones (ibid.) to cut their original 31 items to 18 (resulting in Cronbach's $\alpha = .91$), before confirming convergent and divergent validity of the published instrument. Results showed evidence of unidimensionality with all 18 items loading strongly on their first principal component, explaining 41% of their item variance. They then rotated their component matrix to minimize cross loadings and identify any other score groupings. The seven prompts relating to sameness remained strongest, while five about differentiation grouped on a second component, and six prompts about the centrality of ecological identity to the participant grouped to a third component. Data they collected also demonstrated that this conception of ecological identity influenced a range of environmental behaviors directly and indirectly through worldviews and social values, as measured by the other instruments included in their study. Their final Ecological Identity Scale (EIS) "assesses a form of identity that acts in correspondence across the personal- [person-], role-, and group-bases of

identification" (p. 679).

Despite the EIS's solid foundation, the field may be so saturated with instruments or researchers in different disciplinary areas, or it may be so new, that there are few studies that have used it yet. Cohen Ben-Arye and Halali (2024) adopted it to help identify if ecological identity acted as a moderator of animal advocacy, and Işık Mercan (2022) implemented it to help explain Turkish adults' carbon footprint awareness. A qualitative study by Blanchard and Paquet (2023) to uncover contextual differences in Canadian adults' activation of nature identities concluded that nature-identity tools should build on the EIS, since it includes both individual and social identity and measures both salience and centrality – factors that were revealed as important in their interviews.

Other studies on nature-based identities, not related to PEBs, seek to answer questions about how identities form, the best assessments to measure identities, or other impacts of interventions on identities. Some studies have continued to use Thomashow's (1995) description of "ecological identity" which is best described as a group identity that leads them to align themselves with other environmentalists. There is not a quantitative instrument associated with this construct, so the studies are qualitative. Hayes-Conroy and Vanderbeck (2005) observed, then interviewed, 13 U.S. university students in environmentally-focused courses to add to the literature that "ecological identity" (Thomashow**)** is both individually- and group-formed, involving both sameness and differentiation, but may not lead to emancipatory action (just small-scale change at the duration they were observing). They, and others, have added credence to the importance of cognitive dissonance (McGuire, 2015), critical reflection (Hayes-Conroy & Vanderbeck, 2005), and dialogic processes for identity formation (Schwalbe & Mason-Schrock, 1996; Scott, 2023; Standard, 2023; Trinh, 2021). These three factors tie directly to TL theory, in

which disorienting dilemmas, critical reflection, dialogue, and action are key components.

Transforming Ecological Perspectives and Identities

The types of perspective, worldview, value, and ecological identity transformations required for longer-lasting PEBs and systematic change must be considered and informed through the lens of transformative learning (TL) theory. TL theory describes how adult learners undergo changes to their meaning schemes, their habits of mind and points of view, that make up their frames of reference. These are the structures and processes by which they see and interpret the world around them. These can only change, according to TL, through a process of wrestling with cognitive dissonance, critical reflections, and rational discourse (Mezirow, 2003). Their resultant shifted perspectives of the world are then "more inclusive, discriminating, open, reflective, and emotionally able to change.... because they are more likely to generate beliefs and opinions that will prove more true or justified to guide action" (Mezirow, 2003, pp. 58–59).

The *critical reflection* step of TL is what helps differentiate *transformative learning* processes and outcomes from *learning* and helps differentiate TL from TE. Students may reflect on their learning at three distinct levels – by examining the *content* of what they learned, their own *process* of learning, or on their *premises* that formed their current state of knowledge (Mezirow, 1991). Content reflection occurs as students describe a learning experience – they relay the information they have gained and their observations. They describe the "what" of the experience. During process reflection, students describe the "how" of the experience and lay out the steps they went through to learn the material. This type of reflection may also be considered at the metacognitive level. If learners undergo premise reflection, they are examining their own and other's assumptions, as well as previously unexamined systems of power or oppression that may require revolutionary change (Kreber, 2012; Mezirow, 1990). They are getting at the "why"

questions through instructor-guided role-playing, feedback on journals, experiential learning, discussion prompts, exposure to surprising information, critical incidents reflection, art-based activities, and others (Cranton, 2016, chapter 8). This reflection or soul work puts learners in an uncomfortable, liminal space, just like with identity interruptions, which means it requires tools, supportive social connections, and motivation to work to a resolution.

Despite Mezirow's clear definition and original parameters of TL, continued critique, data, dialogue, new ideas, and misuse of the phrase watered it down over time. Taylor (2007) reviews a structure where Mezirow's view of TL is classified as psycho-critical, but slight shifts in theoretical background or focus have led to psychoanalytic, psycho-developmental, socio-emancipatory, neurobiological, culture-spiritual, race-centric, and planetary views of TL, each with a different lens through which to study, implement, and assess this theory. For Hoggan (2016b), he tackled the problem by suggesting TL theories be classified under a TL metatheory, one of which includes Mezirow's original *perspective transformation*. Hoggan's setup is an analytic, versus Taylor's synthetic, metatheory and defines TL as "processes that result in significant and irreversible changes in the way a person experiences, conceptualizes, and interacts with the world" (p. 71).

Knud Illeris offers a different answer to the critiques of TL lacking a clear definition, or at least to TL losing connection to its Deweyan, Habermasian, Kuhnian, and Freirean roots, by proposing that TL is best defined as "all learning which implies changes in the identity of the learner" (2014, p. 40). To overlap identity theory and TL, Illeris (2014, 2017) claims for Mezirow's ideas of meaning perspectives and frames of reference to be in the personality layer (Figure 1), so that would be the target of TL interventions in education and assessments for change. Under Hoggan's (2016a, 2016b) typology of transformative outcomes across the TL

metatheory, the "self" appears in the literature as one target of change, and Illeris' definition fits squarely here (versus changes in worldviews, epistemologies, ontologies, behaviors, or capacity), though there is overlap. Indeed, in Hoggan's (2016a) study of 206 articles in adult education from 2003–2014, each article had an average of 5 codes (subareas) of transformative outcomes being addressed.

The broader literature on TL, which includes work to redefine it and its application in the workplace, for youth, in informal education, for organizational change, in theological education, and other subdisciplines are extensive and beyond the scope of this literature review. There is a rich literature on TL in sustainability (Rodriguez Aboytes & Barth, 2020) and, to a lesser extent, TL in traditional higher education settings (Kasworm & Bowles, 2012; Moore, 2005) that explore various theoretical propositions and educational interventions that lead to the transformative shifts necessary for societal restructuring to solve sustainability challenges. Here, I review those specific TL topics in service to my three main constructs and research questions.

Higher Education Transformations. Because TL theory originated in a graduate and continuing education setting, some researchers have sought to examine specific questions about its application to higher education in general. These studies usually take one of two scales: The processes and applications of TL theory to classroom teaching and student programming to assess or encourage individual student transformations; or the application of TL theory at the institutional level, to transform the organization or whole institution of higher education to adopt a framework of TL in their work and mission. In other words, it mimics the debate in the TL literature about a focus on individual versus collective/emancipatory transformations. Kasworm and Bowles (2012) give an overview of both scales of study, noting some general interventional suggestions to support TL at the individual level, and examples of programs/curricula and

institutions that have adopted a TL focus. For the former, the goal is mostly helping students develop self-reflective capacity through group projects, collaborative writing, instructor mentorship, experiential learning opportunities (e.g., service learning, study abroad), dialogue, supportive social environments, integration of cultural media, and affective practices (mindfulness, culturally responsive teaching). At the larger scale, curricula, programs, or organizational missions are rewritten or built around TL goals and require a focus on program or cultural shifts often through faculty and staff development (Brunstein et al., 2024; Ehrmann, 2021, Chapter 8; Walvoord & Brunstein, 2022).

Initial work on transformative learning in higher education relied on qualitative studies since the theory was still being formed and no quantitative instruments were available. These studies analyzed observation notes and checklists, student journal entries, and interview transcripts looking for evidence of perspective transformations through changes in values, worldviews, or behaviors (Cranton & Hoggan, 2012). This began shifting in the late 1990s, notably with the doctoral work of King (1997) during which they built the Learning Activities Survey based on Mezirow's 10 phases for perspective transformation through iterative processes of qualitative inquiry and trial runs with university and continuing education students at four private colleges in the NE U.S. (King, 2009). This instrument is still being used (e.g., Reisinger & Clifford, 2022), though validity and reliability have not been analyzed per best practices in instrument development protocols. This tool's usage has slowed with the publication of other instruments and differing ideas on what is most important to measure. Nonetheless, King's (1997) instrument, both in their study and Glisczinski's (2007) who modeled their assessment on King's, found that 37.3% (n = 471) and 35% (n = 153) of adult and teacher education students experienced perspective transformation through a combination of activities they performed in

their respective programs.

Other quantitative instruments have been created and validated by Stuckey et al. (2013) and Cox (2021), following best practices in instrument development, to measure both the likelihood that learners had undergone the processes described by perspective transformation and had transformative outcomes. Beyond the measure of TL processes and outcomes, others have created instruments to measure other parts of the TL framework: Kember (1999) and Savicki and Price (2021) developed and validated tools to assess learners' levels of reflective thinking and writing, respectively, while Walker (2018) developed and validated an instrument to assess the transformative potential of a learning environment. Due to interest in and growing number of TL assessments, reviews of instruments have started to appear (Melcarne, 2019; Romano, 2018) along with a 2021 special issue of the *Journal of Transformative Education* on the assessment of TL (Washburn, 2021, reviews the eight articles therein). The overall call in this field of study is to take the existing qualitative results to create validated quantitative instruments, with clear description of the authors' definition and theoretical foundation, and to use these in more mixed methods studies. This dissertation adopts that latter recommendation.

In answer to this call, the TRansformative Outcomes and PrOcesses Scale (TROPOS) was developed by Cox (2021) as part of his dissertation work and followed best practices in instrument development. His literature review revealed five main concepts for instrument subscales out of which he crafted 59 questions to submit to an expert panel for review of face validity. The resulting 42 items were administered in a pilot study to 12 master's students in a public service management program. Reliability analyses of those data led to a 30-item instrument to field test with 119 graduates of that same master's program. The data from that field test were analyzed progressively with descriptive statistics, correlations between items,

linear regression, and then exploratory factor analysis. The instrument as a whole was reliable (α = .87), with three of the four categories (social support, criticality, and transformative outcomes) surpassing the α > .70 threshold. The *attitude toward uncertainty* questions (α = .65) though not reliable as a group, included questions that were important in factor analysis and one that emerged as a central question, of three, that assessed TL overall. An exploratory factor analysis revealed a 3-factor model that accounted for 42% of observed variance. The first factor (25% of variance) aligned with mostly items from transformative outcomes and criticality questions. The second factor (10%) contained primarily the social support questions, and the third factor (7%) had mostly attitude toward uncertainty prompts. The author suggests further development work to account for even more variance with both prompts in existing categories or exploring new subscales.

As with the nature identity work, summaries and comparisons of empirical TL research are difficult without a common definition, theoretical grounding, and common instruments. Illeris' (2014) redefinition of TL as identity shifts opens a new door of exploration both for developing new instruments to assess TL and for integrating existing assessments (e.g., EIS and TROPOS), to promote research across TL and sustainability education (Walton & Jones, 2018).

Transforming for the Environment. Mandy Singer-Brodowski said it best: "Transformative learning has become one of the most prominent learning theories in regard to sustainable development" (2023, p. 1). This occurred both because TL scholars saw environmental problems as a collective disorienting dilemma on which we and our students could critically reflect towards emancipatory change, and because educators for sustainability and the environment discovered it as a logical construct to apply in reaching their learning outcomes. Researchers from the former group have even called for a redefinition of TL as a shift

towards a planetary or ecological worldview (Burns et al., 2022; O'Sullivan, 1999, 2012). This planetary definition was one of the eight TL perspectives that Taylor (2007) named. This recognition of the importance of TL in sustainability resulted in a special issue of the *Journal of Transformative Education* in 2018 focused on transformative sustainability education (Lange & O'Neil, 2018). Environmental educators exploring TL ballooned at the turn of the century, leading to systematic reviews of related literature published between 1999-2019 by Rodriguez Aboytes & Barth (2020) and again by Viera Trevisan et al. (2024) with different criteria. I summarize that research here, contrasting those reviews, and making connections to ecological identity to show overlap and gaps.

Rodriguez Aboytes and Barth describe a Mezirowian perspective on TL, with recognition of Hoggan's (2016b) metatheory and the diverse processes and outcomes that may have been studied with TL in sustainability over the two decades they reviewed. They were interested in both sustainability education and *education for sustainable development,* a distinction which Lange (2012) claims is important as the latter adheres to a more anthropocentric paradigm. In fact, Ross (2020) even claims that neither of those foci should be the goal of current transformative sustainability educators who seek deeper transformation in learner paradigms. Rodriguez Aboytes and Barth's reviewed articles from three large databases, common for education and the social sciences, using versions of "transformative," "learning," and "sustainability" to get a raw sample of 1,307 articles that were eventually whittled down to 226 full-text downloads for closer review. Of those, 37% were found to have used TL as a central framework (in others it was a buzzword, one of several frameworks, or mentioned as an alternative approach), and about 50% used higher education (university, college, teacher preparation) as their context; in others it was K–12, informal education, or policy papers.

In the 83 articles they classified as having TL as the central framework, Rodriguez Aboytes and Barth (2020) identified content, process, and premise reflections being addressed, though the most common learning outcome they identified was "increase of new knowledge and practical skills" (e.g., Probst et al., 2019) - instrumental, not TL-level learning outcomes. TL outcomes were present, though, in the form of reconstruction of values, norms, and perspectives: Increased sense of connectedness with natural and social surroundings (Bell et al., 2016; de Angelis, 2019); changes in assumptions and worldviews (Papenfuss & Merritt, 2019; Piasentin & Roberts, 2018); and development of a more integrated view of self to lead to promotion of more sustainable actions (Ilisko, 2007). The authors concluded that much of the literature on TL in sustainability is in higher education, though the integration of TL was often weak. If used with more theoretical grounding, it is a rich area of additional research and application for both sustainability education interventions and assessments of TL outcomes. Of note is this review's lack of mention of any nature-based identities.

Highlighting that gap in the connection between ecological identity, TL, and sustainability education is its absence from an even more recent review (Viera Trevisan et al., 2024). While not citing Rodriguez Aboytes and Barth (2020), this newest review also sought to find patterns in the literature on transformative change towards sustainability goals. Their search criteria focused only on higher education, though with a lens towards sustainable development and with the inclusion of organizational transformation (not just individual TL). Their initial search returned 261 English-language articles, which were not further examined or classified for adherence to TL theory. If the prior literature review (Rodriguez Aboytes & Barth, 2020) is any indication, a little under two-thirds of those may have only been using TL as a buzzword, so would lead to errors in interpretation in this review. Coding of these 261 articles was based on

their description of TL stages as: Disruptive event, critical reflection, new perspective development, and new perspective integration (Viera Trevisan et al., 2024, Table 2) which showed up as reflection and critical reflection in their keywords co-occurrence network diagram in the transformative learning cluster (ibid., Figure 3). But this cluster also included teacher training, online learning, pedagogy, and environmental management, which are less aligned than other important TL concepts like dialogue, disorienting dilemmas, and outcomes like mindset, identity, and social shifts.

An important contribution of that study is the call to scale from individual to collective TL in higher education institutions. This study corroborates prior literature reviews showing that education for sustainability in higher education and beyond sees the potential of TL to meet their objectives (Balsiger et al., 2017; Schnitzler, 2019; Sterling, 2011), but with either too shallow an understanding or outright misconceptions of TL theory to integrate it into research and practice in their field (Iyer-Raniga & Andamon, 2016; Thomas, 2009; Tien et al., 2020; Winter et al., 2015).

Actual TL for Sustainability. There are, however, several studies that use theoretically-sound TL theory in education for sustainability in higher education contexts. The work emerging from TL scholars that focuses on sustainability education tends to approach the research with a planetary perspective of TL (Moore, 2005; O'Sullivan, 2012), seeking a paradigm shift in their learners through reconnection to ecosystems and learners' roles in them. Because of this goal and stance on TL, some of these studies integrate Jungian, extra-rational ways of reflecting and knowing, rather than or in addition to the rational, critical self-reflection originally suggested by Mezirow as vital to TL (Burns, 2015; Dirkx, 2012).

For instance, Burns et al. (2022) described their qualitative study of a forest therapy

graduate level course in the U.S. in which forest bathing and other contemplative pedagogies are used to re-awaken the students' relationships to the earth and each other. Through case studies and autoethnography they show evidence of interconnectedness, increased purpose, and peace through practices in nature like deep listening, storytelling, walking meditation, and yoga. Similarly, Hathaway (2022) qualitatively assessed 34 third year undergraduates' journals after five, 30-minutes or more practices (e.g., elemental breaths mediation, walking meditation, intersubjective meditation) to trigger reorientating connections to nature. This Canadian study revealed that students' showed evidence of wider senses of connection to the ecological world and new perceptual abilities. In a historical, multiple case study approach, Walter (2013) analyzed writings and media from and about three environmentalists (Aldo Leopold, Rachel Carson, and David Suzuki) to look for evidence of their phases of TL. The main phases of Mezirow and more Jungian "inner reworking of individual identity and consciousness" (p. 37) were found within their writings and had major influences on them, leading to their deep impacts on the environmental movement of today.

Other studies seemed to rely more on a Mezirowian view of TL while seeking an understanding of sustainability education. Santos et al. (2024) assessed group and written reflections from 173 business students at a Brazilian university, half of which were given a problem-posing case study to discuss while the other half worked through the more common problem-solving version of the case study. Both groups showed evidence of reflecting at the content, process, and premise, levels, but only the problem-posing group reflected on their premises, or assumptions, at the level of emancipation. At the scale of a whole graduate-level course, Wamsler (2020) integrated mindfulness practices that resulted in positive shifts in self-reported well-being, compassion, awareness, motivation, and attentiveness in class. These were

explained by the author as relating more to mindfulness rather than as full TL outcomes. At an even larger scale, an Economics for Transition program at a university in England showed through interviews of eight staff, document analysis, and on-site observations that students and organizations can experience TL if provided space for critical reflection, dialogic processes, a foundation of pluralism, and willingness of learners/administrators to grow (Palma & Pedrozo, 2016).

The literature on transformative sustainability education contributes to the importance of disorienting dilemmas and awe-inspiring reconnections to nature, critical self-reflection and extra-rational practices of reflection, social learning and dialogic processes, and the connection between individual and collective, even emancipatory, change. The literature reveals gaps in the rigor of applying TL frameworks to studies, the absence of the important concept of ecological identity (Brickman & Gormally, 2024), and the paucity of empirical research on the application of TL-promoting practices to higher education. The next subsection explores research on teaching for TE as one potential bridge between teaching, TL, identity, and PEBs.

Transformative Experience

TE is a composite of the learning sciences concepts of interest, transfer, conceptual change, emotion, task value, and motivation (Heddy et al., 2017; Pugh, 2011, 2020; Pugh et al., 2015). Three characteristics help identify that a student has had a TE:

1. The learner notices or is motivated to use a concept they learned in class, but not because of a requirement to do so. That is, they are applying a newly learned concept of their own volition and free-will.
2. Next, the learner changes the way they see everyday objects, events, and issues with the lens of this new concept. In other words, the learner is expanding their perceptions, or

mental constructs that they have previously formed to make sense of situations.

3. Finally, the learner now values the content for its usefulness in everyday experience. This valuing sits at the overlap of interest, perceived usefulness, and feeling.

These three parts can be summarized as *notice-change-value* (NCV), and we can think of a TE as a "learning episode in which individuals actively use newly learned ideas to see and to experience the world in a personally meaningful, new way" (Pugh et al., 2010a, p. 276).

Learners who notice and are motivated to apply some concept they learned in class to their everyday experience, outside of any requirement, are using free-choice transfer (Pugh, 2011). They are practicing the application of a concept they learned in one environment (classroom) to another environment (everyday life). From a neurological perspective, they are creating new neural connections between the concept they were learning and some other, existing experience. This aligns with TE's basis in constructivism because the learner is creating their own meaning of the new concept through this attentional shift. In the next phase of TE, learners' perceptions of situations are changed based on this new noticing of concepts in their everyday life.

Recall, in the previous theoretical background of TL section, mention of meaning schemes – that we learn by incorporating new information into existing schemes, adding new meaning schemes to our existing frames of reference, or create new frames of reference if one does not exist that fits the phenomenon. The perceptual changes in TE align with the second of these, while TL aligns with the third. The last step of TE occurs when students now value understanding this new concept for how it enhances their everyday experiences. This experiential value includes parts of what Wigfield and Eccles (1992) described as intrinsic and utility value and what Hidi and Renninger (2006) called individual interest. That is, students intrinsically

enjoy or are fulfilled by applying new information and they find it useful, both of which are related to them showing an interest in the material by using it outside of class (Pugh, 2011).

Promoting and Assessing TE. To assess whether learners have had a TE, a self-report survey can be used, the most validated of which is the Transformative Experience Questionnaire (TEQ; Koskey et al., 2018; Pugh et al., 2010a) developed using mixed methods procedures with 196 middle and high school students. The TEQ includes 27 prompts, none reverse-coded, that contain 9 prompts about each of the 3 subcomponents of TE. That is, there are nine questions about *motivated use*, *changed perception, and experiential value*, respectively. Each rating scale category provides a distinct progression along the variable to indicate higher TE with higher scores, though the three components did not cluster in principal components analysis during that study. The instrument showed reliability of $\alpha = 0.96–0.98$ across items. The TEQ is therefore a holistic measure of TE as a form of engagement with behavioral, cognitive, and affective dimensions. Koskey et al. (2018) confirmed the instrument's reliability even with wording changes for different science topics (e.g., properties of matter, genetics).

Data seem to indicate that TE "at the secondary education level appear to be relatively rare in the absence of instruction designed to foster them" (Pugh et al., 2019, p. 6). *Teaching for Transformative Experiences in Science* (TTES) is one such intervention developed to increase the likelihood of students having TE in science, the domain from which TE was initially formed. It involves the instructor describing how a course concept is important in everyday life, sharing an example of their own NCV reflection (i.e., one of their transformative experiences), and giving students several rounds of practice with feedback (scaffolded) (Heddy & Sinatra, 2013).

Much of the research in TE has been carried out in K–12 settings and has some application to higher education as well, so they are briefly summarized here. Results have

included high school biology students' conceptual change about natural selection, especially when linked to science identity, that is, students seeing themselves as future scientists (Pugh et al., 2010a). The integration of TTES was shown to have interactive effects with other science teaching methods, like teaching for conceptual change, for positive transfer, and knowledge acquisition with high school biology students (Pugh et al., 2010b). For fifth grade students, teaching for transformative and aesthetic experiences led to more, and more enduring, learning of science concepts (Girod et al., 2010). When TTES was combined with parent involvement in seventh and tenth grade chemistry and biology students, they showed an increase in perceived experiential value of their course concepts (Heddy & Sinatra, 2017).

For college and adult learners, researchers have tried integrating TTES by asking students to keep a NCV journal, post to a discussion board, or post a video reflection in which they pick any new concept over X number of weeks (e.g., for the unit being covered), then talk about when they noticed that concept outside of class, how it changed their perception, and why/when they found it important or valuable to now know or understand that new information. These discussions can be done during synchronous class in small groups or asynchronously via online discussion boards where students are required to respond to peers (Heddy et al., 2017; 2021). The important aspect of this third strategy of TTES is the instructor guiding and prompting the students to correctly explain their NCV progression.

TTES interventions in higher education have been applied to students of different ages, majors, and topics (Pugh, 2020), including in non-science courses, like social studies (Alongi et al., 2016) and college success courses (Heddy et al., 2017). Results of TTES interventions in higher education have included college education majors' conceptual change about evolution, increased incidence of TE, and enjoyment of learning in a biology class (Heddy & Sinatra,

2013). In another TTES intervention study, first-year nonbiology majors had a greater appreciation for the topic of evolution (Sparks & Darner, 2020). Pugh et al. (2021) studied major and career choice of geoscience students as correlated with their geoscience identity/interest, gender, self-efficacy, TE, and other factors. They found that TE played a role in predicting academic and career choice, but only for female students across their alternative models. This study was the rare case in which difference between TE's use with majors or nonmajors has been studied, which could be important for understanding student interest, motivation, identity, and how to structure interventions for nonmajors ecology education. Heddy et al. (2021) also found a gender difference in their study of online engineering students where *perceived instrumentality* of course content was only a predictor of TE in females and those who did not participate in NCV reflections, suggesting that TE may be more short-term (as perceived instrumentality is more future-oriented in the way it is measured).

In summary, implementing teaching practices in K–16 education that encourage students to have transformative experience have shown promise in improving student success as measured by their conceptual change and their increase in transfer, interest, enjoyment, and content acquisition. It is not yet known if interventions, like TTES, are needed in the same way in higher education as they are in secondary education to promote students having TE. Characteristics of higher education learning environments and of the learners themselves (e.g., interest, emotions, identities) could promote TE in adult learners (Pugh et al., 2019).

The hypothesized results of students in nonmajors introductory biology having TE in their ecology unit would be students who are using, perceiving, and valuing ecological concepts in the world around them outside the class. These students would leave that ecology unit placing more value on ecological concepts. The nonmajors introductory biology context must be

examined to determine baseline data on what transformative goals and teaching may already be present in nonmajors' classrooms and to measure if transformative learning experiences and ecological identity shifts are already occurring for students, even without interventions like TTES. The next section will propose a linear relationship between TE, TL, and identity in the context of undergraduate education for sustainability and the environment.

The Proposed Three-Construct Overlap

This subsection explicitly points out potential overlaps between the three constructs being explored: Ecological identity, transformative learning, and transformative experience. Despite growing interest and research on transformative learning in sustainability, and a proposed definition of TL as shifts in identity (Illeris, 2014), there is no mention of ecological identity in the TL literature. TL in sustainability is often tied to greater connectedness with nature and mental health benefits, but it falls short of tying the outcomes of TL to transformations of ecological identity. Hathaway (2022) notes that, in his students, he saw increased "appreciation for beauty, and a sense of connection or an expanded self" (p. 298). Rodriguez Aboytes and Barth's review (2020), however, mentions that amongst TL learning outcomes, they saw evidence of learner's experiencing self-awareness and more integrated identity as manifested by promoting sustainable actions (p. 1003). Adopting the identity definition of TL, or at least as the chosen transformative theory within TL metatheory, will give a rich area of research to explore in TL for sustainability and in the education for the environment and sustainability fields.

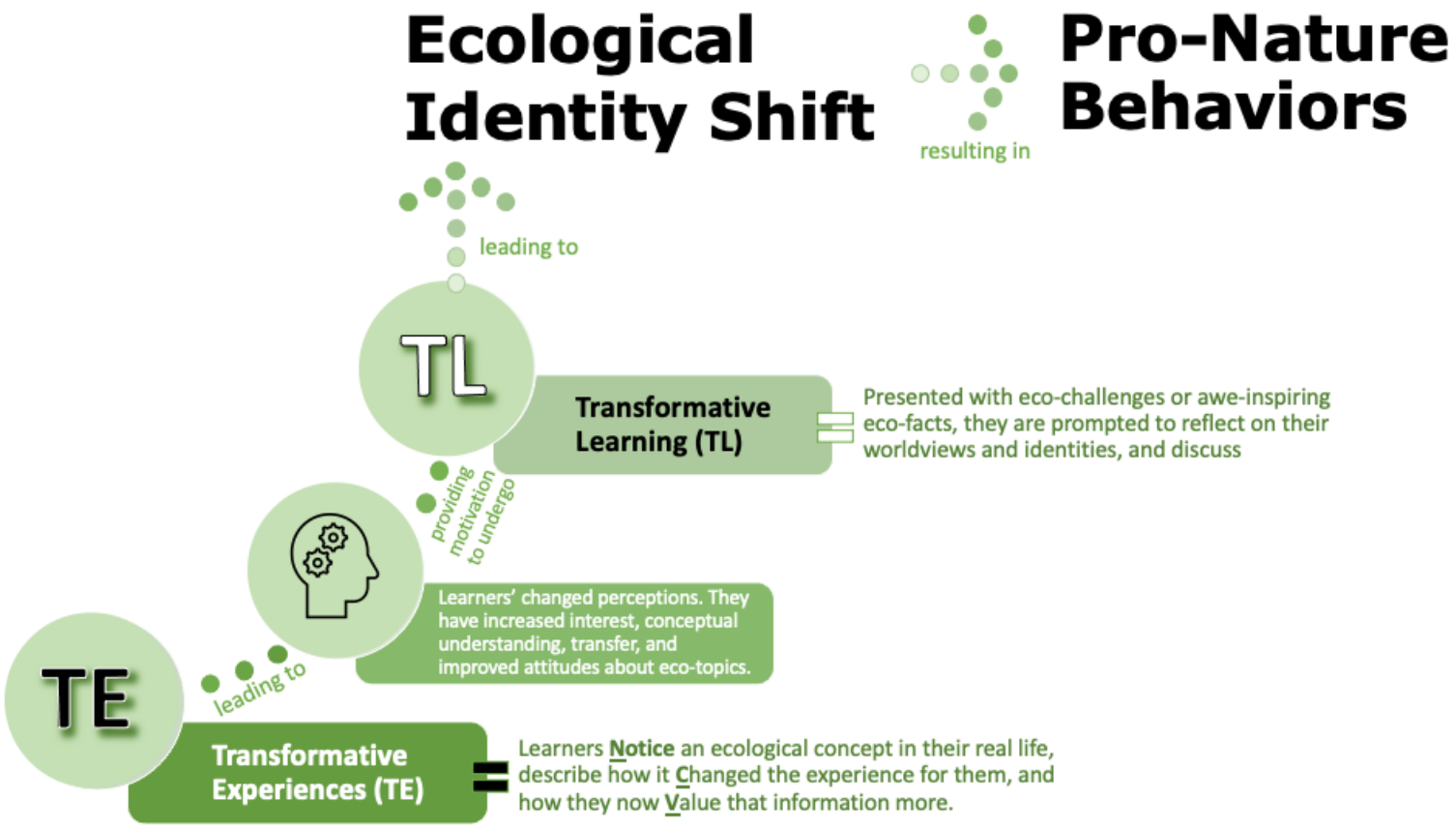
The literature on TE does not explicitly discuss the theoretical ties between TE and TL, with only a few authors mentioning both constructs (Crawford, 2018; Heddy & Pugh, 2015; Pugh, 2020; Singleton, 2015; Walker, 2018). Singleton invokes both TE and TL in her call for place-based education in elementary schools to promote sustainability but without differentiating

them. Crawford's dissertation and Walker refer to TE as a type of TL much like Pugh's work refers to TE as a micro-TL, wherein perceptions of specific concepts change through transactional teaching (Heddy & Pugh, 2015) as opposed to worldviews or identities transforming through transformational teaching. Heddy and Pugh promote TE as more manageable to implement at the classroom level with its established pedagogies and that the accumulation of several TEs may "lead to the type of transformative learning that influences student identity" (p. 1).

While TE is defined by students' content and process reflections leading to their changed perceptions about a subject (e.g., ecology concepts), the types of reflections required in TL are on one's assumptions (premises) leading to lasting worldview or identity shifts (e.g., ecological identity) (Mezirow, 1991). This reflection on premises that is called for during TL processes is qualitatively different than the type of reflections used to integrate TE into a classroom where students reflect on their noticing, changing perceptions of, and valuing a particular course concept. So, while it is possible that more and more TEs across different concepts in the same course may lead to the sorts of TL outcomes previously discussed (Heddy & Pugh, 2015), those outcomes should be more likely if TL practices are integrated into courses. Even without an instructor's focus on conceptual learning, learning for aesthetics, or transformative learning, transformative outcomes may happen, but it is not part of an intentional educational environment. Just as restructuring activities to encourage TE will increase students' aesthetic experiences (and other related outcomes, like transfer, conceptual change, transfer, and positive emotion), fostering students' premise reflections and extra-rational practices, like mindfulness, means they will be more likely to examine and transform their perspectives, worldviews, identities, and pro-nature behaviors. This proposed relationship is illustrated in Figure 3.

Figure 3

Proposed Relationship of Transformative Experience, Transformative Learning, Ecological Identity, and Pro-Nature Behaviors



Note. Figure drawn by the author

Dewey's aesthetic understanding of learning, out of which both TL and TE have grown, refers to the importance of nature, as stated by Wong et al. (2001): "For Dewey, we believe, identity also included one's relationship to or participation with the world (natural and social) as made possible by ideas" (p. 335). Despite this, there is no direct mention of nature identity in the TE literature, though it commonly mentions science identity as a factor in students' likelihood of undergoing transformative science experiences (Pugh, 2011; Pugh et al., 2010a; 2021). In this context, though, it is conceptualized as the degree to which a student sees themself as a science person or future scientist - a role-based identity. This is different than the construct of ecological identity in which any person can see themself as part of the ecosystems in which they live. Also, from this theoretical foundation, identity has been found to be fluid into a person's twenties, so any shifts in identity in a K–12 setting would be more about identity formation than transformations in identity. If we apply Heddy and Pugh's (2015) hypothesis about students' TE over ecological and sustainability concepts accumulating to the point of TL shift, we could conceive of changes in their ecological identities as well. This has not been studied and is another rich area of inquiry.

Because TE can improve students' interest, enjoyment, and conceptual understanding of science topics, integrating *teaching for transformative experiences* pedagogies could act as a bridge to increase the incidence of students' undertaking the premise reflections necessary to transform their ecological identities during course units on ecology and sustainability. Including both TE- and TL-based teaching practices should lead to a higher prevalence of ecological identities moving to a more central location, or higher in the identity hierarchy, resulting in higher incidences of pro-nature behaviors (Figure 3). To uncover this relationship, it is important to know if nonmajor introductory biology instructors already include transformative teaching in

their courses. The next section describes a research project to help answer that question to begin an exploration of the three aforementioned constructs.

Chapter 3: Research Methods

Research Design Overview

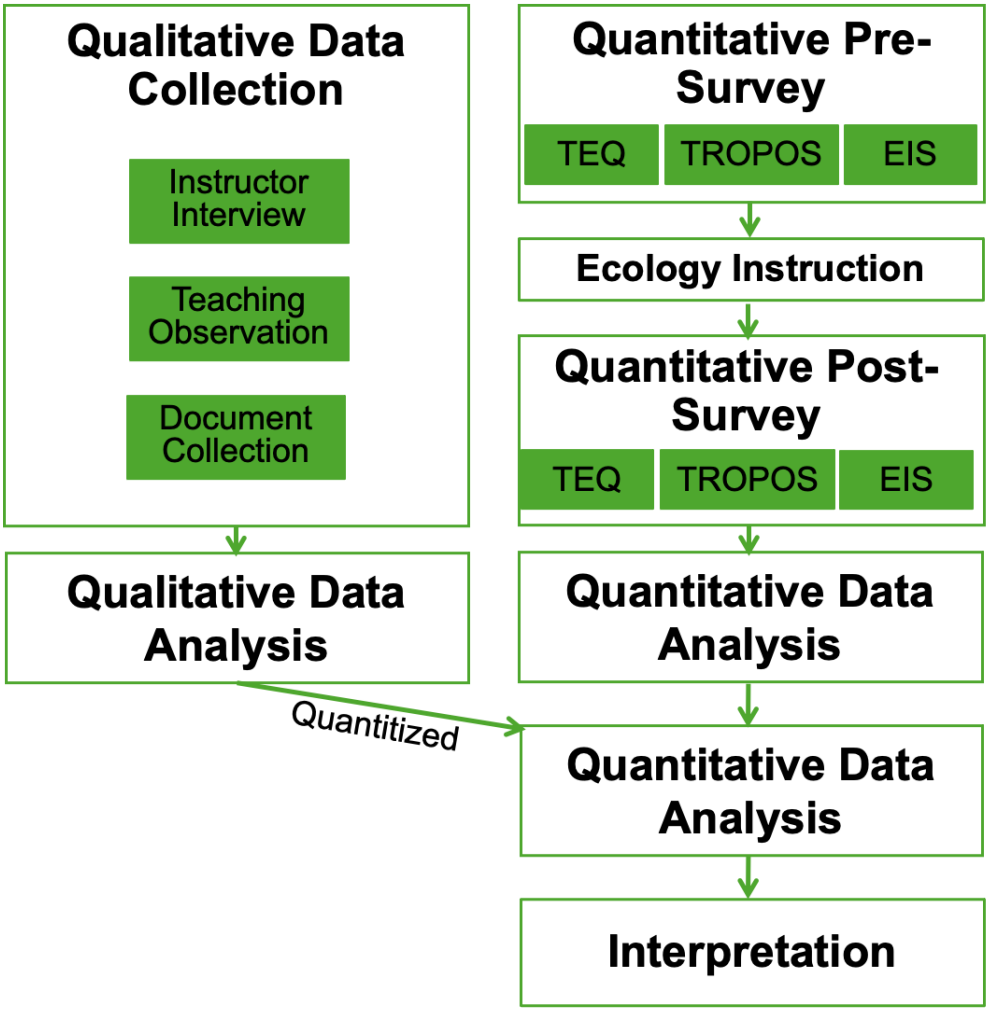
I explored the presence and interaction of three constructs during the teaching of ecology and environmental topics in select nonmajor introductory biology sections at universities. My main research question asked: Are transformative methods used for teaching ecology topics in nonmajors introductory biology, and what are the relationships between those teaching strategies and student shifts in transformative experience (TE), transformative learning (TL), and ecological identity? Specifically: 1) What is the nature of transformative teaching in the ecology unit of a sample of nonmajor introductory biology sections? 2) To what extent does instruction that includes transformative teaching strategies predict students' transformative experience, transformative learning, and ecological identity shifts? And 3) To what extent does transformative experience mediate changes in students' transformative learning and ecological identities?

By gathering data from nonmajor undergraduate students and seven instructors across three campuses and two states, I sought to learn about students' shifts in TE, TL, and ecological identity, and where differences existed, examine the presence of transformative teaching methods over ecology concepts by instructor. For this mixed methods research, I gathered qualitative data on biology instructor teaching through observations, interviews, and document analysis from their introductory biology course sections. Concurrently, I collected quantitative data from students in those introductory biology sections using self-report, pre-post surveys to measure their TE, TL, and ecological identity. After initial analysis of the qualitative data (coding thematic summaries of the observations, interviews, and documents) and quantitative data (descriptive statistics of the survey results and other analyses), qualitative data were

quantitized for another round of quantitative analyses (Figure 4). This study can be classified as convergent mixed methods research, notated as: qual + QUAN = converge results (Creswell & Plano Clark, 2018).

Figure 4

Overview of Convergent Mixed Methods Research Design for this Study



Note. TEQ = Transformative Experience Questionnaire; TROPOS = TRansformative Outcomes and Processes Scale; EIS = Ecological Identity Scale. Figure drawn by the author.

Since this is a new area of inquiry, baseline data needed to be collected prior to

undertaking any intervention research on these constructs. My study, described below, used a small number of cases to uncover the presence and nature of transformative teaching strategies in nonmajors introductory biology instruction over ecology and to explore shifts and relationships between students' TE, TL, and ecological identity in those same course sections. Results serve to inform future studies and can guide the design of TE and TL teaching interventions towards TE, TL, and ecological identity learning outcomes in biology and environmental education.

I used maximum variation and opportunistic sampling (Creswell & Poth, 2018) to choose instructors and their nonmajor sections for this study. Through personal contacts and networking around a professional biology education organization, I reached out to instructors of nonmajors biology from two countries (two provinces in Canada and four states in the U.S.) who taught various sizes and modalities of introductory nonmajors biology. Those who ended up participating included nine face-to-face and one online section of nonmajors introductory biology taught by seven instructors from three universities and two states participated as the population sample to provide some variation to answer my research questions. The distribution of students across those sections was not completely random, because course sections differ in day/time offered, peer influence on choice of enrollment, or other unknown factors giving the potential for clustered data by section, instructor, campus, or state. This was considered while interpreting data.

A total participant sample size of 130 students was needed as revealed by power analyses (G*Power, version 3.1 for Mac) for a repeated measures ANOVA with .23 effect size (average of partial eta-squared values for my three instruments from pilot data), .95 power, and 9 degrees of freedom to test for differences survey responses by instructor. To help minimize any effects of attrition on study reliability, double that total number of student participants was sought (i.e.,

260). I reached out to 15 instructors to try to reach a goal of 10 participating instructors across 2 states within my bounded system of study. Since seven instructors were eventually recruited, this helped solidify the justification for including qualitative data from instructors in answering my research questions.

Because one of the universities includes a commitment to transformative learning experiences in its mission, transformative learning as a value, and a campus-wide program in place to implement that commitment (Ehrmann, 2021, Chapter 8; King & Wimmer, 2020), a higher prevalence of TL teaching methods was expected from sections at that university compared to the others which did not include any mention of transformative learning in their mission, vision, or values. I further hypothesized that students enrolled in course sections in which the instructor used more TE strategies would have significantly greater shifts in TE; those sections including more TL strategies would have students with greater shifts in both TL and ecological identity; and sections with evidence of higher identity, TE, and TL strategies would facilitate greater shifts across all three constructs (Garner et al., 2016; Heddy & Pugh, 2015; Kokkos, 2017). Finally, I hypothesized that TL and ecological identity outcomes would be significantly and positively correlated, since TL has been defined as shifts in identity (Illeris, 2014; 2017).

Context and Participants

Undergraduate biology courses include ecology instruction during which students are taught about human impacts on our biosphere. Many nonmajors take introductory biology for their required general education science credit, so it provides an important location in higher education through which nonmajors' ecological literacy and identities are impacted (Gardner et al., 2016). Nonmajor courses should be taught differently than courses for majors, because of

different learning outcomes and because of varying interests, motivations, and identities between the two groups (Cotner et al., 2017; Hebert & Cotner, 2019; Knekta et al., 2020).

Characteristics of non-science majors include them holding more misconceptions about the nature of science, seeing less relevance of the topic to their lives, and having more diverse backgrounds, skills, and perceptions of biology than STEM majors (Cotner et al., 2017; Hebert & Cotner, 2019). Further, nonmajors in introductory biology have self-reported that they had significantly lower positive feelings towards the subject, lower perceived personal value of biology, and less voluntary re-engagement with biology-related content compared to biology majors (Knekta et al., 2020). These affective differences impact student learning, but as we have already seen, can be positively skewed by integrating practices such as those that encourage student transformative experience (Heddy & Sinatra, 2013; Sparks & Darner, 2020).

Not only does this attenuated interest and motivation reported by some nonmajors lead to challenges in course or college persistence, but it has an impact on the current and future communities in which they reside. For example, individuals' scientific knowledge after college has been tied to personal health choices (Kahan, 2013), support of scientific research (Sanz-Menendez et al., 2014), and science policy opinions (Ding et al., 2011), which shows the broader impacts of science education on our society, not just on individuals or families.

Taken together, these studies and others convey the necessity of designing, teaching, and/or assessing nonmajors biology courses differently than biology courses for majors (Brickman & Gormally, 2024; Laetsch, 1967), both for the goal of college student success and for the greater social good that citizens with more core ecological identities would perform. The question remains as to the course designs and learning activities that could be built, using what is known about the positive impacts of TE, TL, and ecological identity shifts, for nonmajors

introductory biology to accomplish these goals.

For the quantitative portion of the study, 403 students completed the pre-survey, 310 the post-survey, and 262 completed both pre and post surveys across the 10 course sections, 7 instructors, and 3 universities located in 2 states in the United States (Table 1). As described in more detail later, 3 outliers identified through box plots and examined individually for short response times and inconsistent answers, were removed, leaving a total sample of 259 pre-post matched survey respondents. Campus 1 is a large, residential, four-year research university located in the Midwest; campus 2 is also a large, residential four-year research university but is in the Midsouth; and campus 3 is a large, nonresidential, four-year comprehensive university located in the Midsouth.

Table 1

Instructor and Section Participant Summary

Instructor	Campus	n	Course Size	Modality	Observation	Interview
Hazel	1	60	120	f2f	none	online-s
Ava	1	91	225	f2f	online-s	online-s
Lucas	1	30	90	f2f	online-s	online-s
Jack [a]	2	2	31	online-a	online-s (combined)	
Sam	3	12	39	f2f	f2f	f2f
Maggie	3	13	35	f2f	f2f	f2f
Gabe [a]	3	51	124	f2f	none	online-a

Note. n = number of pre-post matched student participants by instructor; f2f = face to face; online-a = online, asynchronous format; online-s = online, synchronous format.

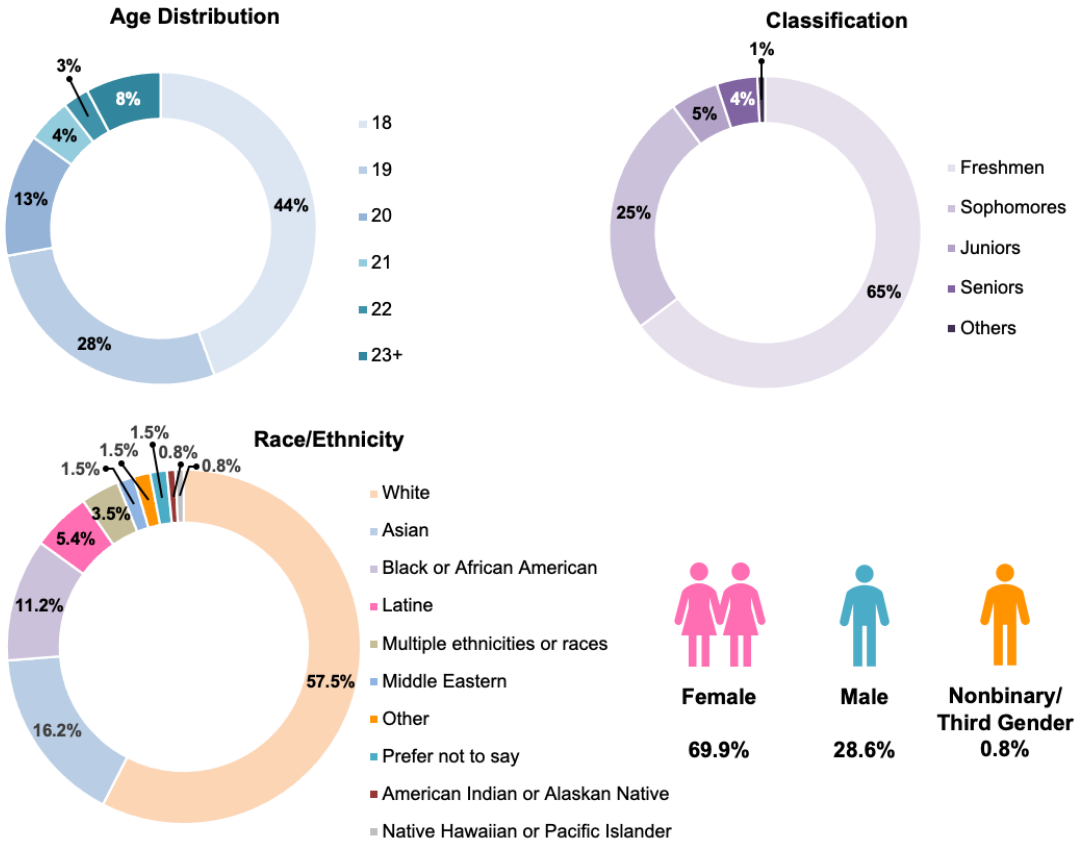
[a] Documents were examined from Jack (course website) and Gabe (three assignments).

Three participating instructors from campus 1 teaching three large sections had 181 pre-post matched student participants while 4 instructors from campuses 2 and 3 teaching 7 smaller sections had 78 pre-post matched student participants (Table 1). The course section at campus 2

was taught in an online, asynchronous format while the others were face-to-face. Five instructors were observed teaching ecology content live, one (Hazel) was not observed since the ecology unit had already been taught by the start of the study, and one (Gabe) did not include the teaching of ecology as a separate unit or lecture in their sections. Six instructors were interviewed synchronously while one chose to respond asynchronously to interview questions (Table 1). Student pre-post matched participants averaged 19.5 years old (median = 19, range 18–42) and were mostly first year (64.5%), female (69.9%), and white (57.5%) (Figure 5).

Figure 5

Demographic Summary of Student Participants Matched on Pre-Post Surveys (N = 259)



Qualitative Research

The qualitative portion of my study used a case study research design to examine seven nonmajor biology instructors' goals and methods for teaching ecology content to their students.

The bounded system for these cases was instructors of nonmajor introductory biology courses during the fall 2024 semester at selected four-year universities in the United States. I used a multisite design to begin to understand the presence and diversity of transformative teaching methods used in the ecology unit of nonmajors introductory biology. To choose cases for this study, I employed a combination of maximum variation and opportunistic sampling (Creswell & Poth, 2018). Through personal contacts and networking within a professional biology education organization, nonmajor biology instructors from two different states who taught large enrollment face-to-face, small-enrollment face-to-face, and a small asynchronous online section at both research-intensive and a teaching-focused four-year university participated in qualitative research.

Though in quantitative research the goal is unbiased collection and interpretation of data, qualitative research recognizes and uses researchers' and participants' humanness in seeking answers to research questions. Therefore, a description of my positionality as the researcher involved in this study is necessary to explain my use of reflexivity to increase trustworthiness of findings. Having taught nonmajors introductory biology for 15 years and led faculty training about transformative learning for over 9 years, I brought an emic (insiders), perspective to this qualitative portion of my research. My background and experiences in biology, transformative learning, and teaching influenced the questions I asked, how I set up my methods, and how I have interpreted my results (Schutz et al., 2004).

The advantage to this emic positionality is that I was able to connect with the biology instructors quickly, have a better idea of the best questions to ask, and have an intrinsic motivation to perform and complete quality research since the findings could apply to my own teaching and work. In addition, sustainability is a problem-framing field – that is, it is problem-

focused, considers different worldviews/epistemologies from different fields, and is impact oriented. By approaching this study of environmental education considering constructs from three different disciplines (educational psychology, adult learning, and sociology), a transdisciplinary approach was needed (Hirsch Hadorn et al., 2006). Though I am not carrying out collaborative research for this dissertation with expert researchers from different fields of study as recommended for transdisciplinary research, I am bringing experience from biology education, adult learning, and educational psychology myself.

The disadvantages of my emic positionality are that I may have entered the research with expected outcomes or biases in interpretation of the data. To protect against this, I sought guidance of another researcher (my doctoral advisor), kept my emic perspective front-of-mind as data were coded and interpreted, and incorporated both quantitative and qualitative data – using a pragmatic mixed methods approach (Creswell & Plano Clark, 2018).

Qualitative Data Collection

Qualitative data were collected through observation of biology instructors during the ecology unit of their courses, through one-on-one interviews, and through document analysis (e.g., a course assignment). These three sources were used to triangulate the data to get a more in-depth picture of instructors' intended learning outcomes for their students and the methods they used to meet those outcomes. Observations contextualized the data being collected in the classroom setting. This triangulation of data from three sources also helped improve trustworthiness of the findings in these select cases. Details about these sources of qualitative data and how they were examined are described below.

Instructors were observed teaching ecology to their course in real time, either in person or via virtual attendance (i.e., Zoom), depending on their preference and feasibility of my travel to

their location. The instructors chose the course session that they wanted to have observed, both to help them be more at-ease during the session and to help build the relationship between the researcher and participant. Of the seven instructors, two were observed via Zoom, two were observed in person, and three were not directly observed (Table 1). Of those latter three, Hazel had already completed the ecology unit by the time the study began, Gabe did not teach a stand-alone ecology unit during his biology course so there was nothing to observe, and Jack's section was an online section in which no recorded or live ecology content was delivered (i.e., it was an asynchronous online course). For these latter three instructors, qualitative data were limited to two of the three sources – interviews and document analysis.

During the observations of the four instructors, I watched for elements of teaching across seven categories, recording those on an observation sheet as both counts of times seen and examples of that type of teaching (example row in Table 2; see Appendix A for full sheet). During in-person observations, I sat in the back of the class with a clipboard that held the observation sheet on which I made manual tabulations and notes of what I observed. During Zoom observations, the classroom cameras were pointed at the front of the room where the instructor, lecture screen, and sometimes the backs of some students were visible. The observation sheet was filled out electronically during these Zoom sessions. For all four live observations, within 24 hours of observing the class, I revisited the observation sheet to convert paper forms to electronic and to check tabulations, edit notes, confirm coding selections, and add additional details to my notes. This revisiting of the observation data enhanced reflexivity on how I was interpreting what I had observed, given my inherent biases, to help ensure trustworthiness of the data.

Table 2

Instructional Observation Sheet Sample Row

Categories	Count	Examples
1. The instructor's sharing of how they notice(d) ecology concepts in their everyday life		

The categories used for the observation sheet (Appendix A) were based on the three subcomponents of TE – motivated use, changed perception, and experiential value (Koskey et al., 2018) – and on the four main categories of transformative environments that facilitate transformative learning, as identified during the development of the Transformative Learning Environments Survey (TLES) – disorienting dilemmas/awe, critical self-reflection, critical discourse, and changed behavior, as the outcome of having experienced TL (Walker, 2018). The characteristics of instructor statements that were coded in each subcategory are described below, since a codebook was assembled for the interview protocol that included these same coding categories.

Interview questions for instructors were drafted ahead of time by the researcher, checked by an expert in educational psychology, and were written to gather evidence of learning outcomes and teaching methods across the three constructs – transformative experience, transformative learning, and ecological identity (Appendix B). They expanded on the observation sheet themes by asking about instructors' learning outcomes for their students in their ecology unit, how they model or tell stories about their own transformative learning experiences, and in- or out-of-class activities that they think promote transformative growth or identity reflections. For example, each interview began with the question, "What do you hope

students can do if they fully participate and complete the ecology unit of your course?" usually clarified with the follow up, "...not what they will know, but what they can do."

One-on-one interviews were conducted around the time of the instructors' teaching of their ecology unit in their course, so that their assignments, activities, and lectures would be fresh on their minds. The format of interviews was semi-structured (Creswell & Poth, 2018) and were either in-person (2 instructors) or online via Zoom (4 instructors), depending on instructor preference (Table 1). The exception was Gabe who chose to answer interview questions via online survey (Qualtrics), which did not allow clarifying questions to be asked but provided time for the instructor to draft thoughtful responses. For Jack, who taught an online, asynchronous section, our Zoom-recorded one-on-one session included both a "tour" of the course, which acted as a combination of classroom observation and document analysis through screenshare, and the semi-structured interview.

The in-person interviews were audio recorded using a handheld digital recorder and Zoom interviews were screen recorded to the cloud for later review. Audio recordings were uploaded to YouTube for automatic transcription, which was later checked for accuracy and corrected; video recordings were automatically transcribed by the software but later checked for accuracy and corrected. Only Gabe chose to submit documents, three course assignments, for further review. An example page of a transcribed interview is provided in Appendix C. Details on analyzing these qualitative data sources are provided in the qualitative analysis section below.

Gabe did not lecture on ecology but did give students three assignments that covered ecology content. These documents were submitted for data collection as was Jack's course website. Coding for these documents followed the same protocol as instructor observations. That is, evidence of TE motivated use, changed perception, and experiential value (Koskey et al.,

2018) and of TL disorienting dilemmas/awe, critical self-reflection, critical discourse, and changed behavior (Walker, 2018) were noted during document review (Appendix A). Reflexivity on the instructor goals and underlying purpose behind assignment components were considered when coding to increase trustworthiness of findings.

Qualitative Analyses

The observation matrices from instructor teaching of ecology and the submitted instructor documents were imported into NVivo (version 15.1.0) to aid in their analysis. Both the document wording and the notes of examples taken during live observations of the 50-minute course durations were examined instructor by instructor to code to subcomponents of two of the a priori construct themes: TE motivated use, changed perception, and experiential value; and TL disorientation/awe, critical reflection, critical dialogue, and TL outcomes (Appendix A). Since interview coding included those seven, as well as two more identity subcomponents, details are given in interview analysis paragraphs below.

Transcripts of the audio and video instructor interviews and Gabe's interview survey response were imported into NVivo (version 15.1.0) to organize, code, and understand themes. As I read through transcripts to correct them, I was also reading for potential evidence of transformative teaching, including mention of identity, prior to my main coding cycles. For the first full read-throughs of instructor interviews, deductive coding was used to look for instances of the subcomponents of TE (motivated use, changed perception, and experiential value), TL (disorientation/awe, critical reflection, critical dialogue, transformative learning outcomes), and identity (either nature based as a person identity or science identity as a partial identity). A codebook was created in NVivo, giving descriptions of each of those, to increase reliability across coding sessions (Appendix D). While reading each transcript to assign responses to these

codes, I also started a new folder of codes that emerged more inductively (which are not included in this study).

TE motivated use was assigned when the instructor described a desire for, or an activity that would motivate, their students to notice one of the ecology concepts they learned in class, outside of class in their everyday lives. *TE changed perception* referred to instructor mention of their learners changing the way they see everyday objects, events, and issues using the lens of a new ecology concept. Instructor comments were coded as *TE experiential value* when they indicated or implied that they aimed for their learners to now value ecology concepts for their usefulness in students' everyday experience.

For the TL subcomponents, *disorientation/awe* was assigned when the instructor mentioned goals or activities that sought to introduce information that upset, frustrate, or surprise learners to drive them to critically reflect on their previously unexplored assumption/worldview about some ecology topic. *Critical reflection* was recognized when the instructor prompted students with "why" questions, displayed a desire for their learners to confront previously unexamined systems of power or oppression, and/or provided a supportive environment for this deeper work. *TL critical* dialogue was used as a code when instructors described their activities or goals of students' sharing of critical reflections with each other; or of their setup of a supportive environment that would encourage these deeper dialogic processes. The final aspect of TL, *outcomes*, refers to the instructors' goals for their students to have a permanent shift in ecological worldview, perspective, or identity; and/or their desire for, or providing opportunities for, their students to act out this new worldview, perspective, or identity.

Due to the overlapping ideas of *TE changed perception* and *TL outcomes* (expanded perspectives), coding for those phrases took closer examination and use of interpretation through

thick description. Thick description is a qualitative method that seeks the meaning under-the-surface of data. Expanded perspectives should lead to action, according to the literature (Mezirow, 1978) and can also change the way individuals perceive and make meaning of situations. Phrases were coded to *TL outcomes* if there was indication of broader worldview shifts versus changed perceptions about a certain ecology concept. For *TL critical discourse*, instead of only identifying phrases in this code if critical dialogue was indicated, I ascribed to Cox's (2021) explanation of the importance of creating a socially supportive environment where critical dialogue could take place as being important to transformative learning. In this way, instructor mention or observation of activities that helped create a classroom atmosphere where diverse perspectives and difficult questions could be explored were also coded to this TL subcomponent.

Identity was not a separate category on the observation matrix, but the interview questions did include a prompt about identity. Instructor responses were categorized as either *nature identity* or *science identity*. Ecological identity is a type of nature (person) identity and science identity is a partial identity, but both were important to capture since Illeris (2014) argues that transformative learning can be identified by identity shifts. *Nature identity* referred to instructor responses that indicated they had the goal of, or described activities that prompted, learners' seeing themselves as part of nature. *Science identity*, on the other hand, was used when the instructor described goals or activities that helped students see themselves or others as scientists.

For error-checking and to increase validity, a second round of interview transcript examination took place several days after the initial analysis by reading through each response grouped by initially assigned deductive codes, instead of by instructor, to determine if any code

reassignment of phrases should take place. In addition, for phrases that I had difficulty classifying, I sought the opinion of an expert in educational psychology not directly involved with the study. That peer debriefing provided valuable feedback on my coding and qualitative interpretation. Together, the iterative coding process and peer debriefing helped ensure reliability of the coding and trustworthiness of the findings.

After the deductive coding and code-checking was completed for observations, documents, and interview data sources, qualitative analyses took place using a within case analysis of the seven instructors. These data were then thematically analyzed across the cases (cross-case analysis) to identify trends and answer my research question about the nature of transformative teaching in these cases (Creswell & Poth, 2018).

In qualitative research, rigor in data collection, analysis, and interpretation are all important components to consider to increase trustworthiness. This study included some of those best practices (Cresswell & Poth, 2018). Trustworthiness of these qualitative data were ensured through triangulation of data sources (observations, documents, and interviews), peer debriefing for both the interview prompts and the assignment of codes through weekly or every other week meetings with my research advisor, reflexivity as acknowledged in my positionality statement, and thick descriptions to best understand the meaning under-the-surface of instructor wording as I worked towards themes across the seven instructor cases.

Quantitative Research

This research gathered quantitative data from nonmajor biology undergraduates on three survey instruments – the Transformative Experience Questionnaire (TEQ; Koskey et al., 2018), TRansformative Outcomes and PrOcesses Scale (TROPOS; Cox, 2021), and Ecological Identity Scale (EIS; Walton & Jones, 2018) (Appendix E). These self-report surveys were selected

because of their alignment with the theoretical foundations of my work, the more rigorous instrument development procedures used to create them versus alternative instruments, and their high reliability both in their original development and in my pilot research (Walvoord & Heddy, 2025). Students enrolled in nonmajor introductory biology sections of the participating instructors were recruited to take the pre-surveys during the middle of the semester and then again during the last week of the semester as post-surveys (Figure 4). Descriptive statistics were run on the resulting pre-post scores, and they were then analyzed in relation to the qualitative data (observations and interviews). I provide additional details in the next subsection on the quantitative portion of the study.

Variables that were standardized to minimize some sources of error in the survey responses include that the study took place during the same semester at all sites and that the locations were all at 4-year universities in the United States. Variables I did not control, nor gather data to control in post-hoc analyses, included sociohistorical factors (e.g., external stressors, like family, finances, relationships; prior nature trauma; and the influence of content from other courses), differences in physical learning environments across the sections, and variation in campus cultures. Any of these could have been sources of error and help explain differences in student scores or be factors to include in future research. Demographics of the students (e.g., age, year of study, major) were collected on the surveys to provide a better picture of the population, and qualitative data about instructor teaching through observations and interviews were examined for impacts on student score variation.

Quantitative Data Collection

Approximately half-way through the semester of their nonmajor courses, students in the potential recruitment pool were invited to participate in the study either in-person by the

researcher, online synchronously by the researcher, or through posting of the IRB-approved recruitment text to the section's online learning management system. The method was determined in consultation with the instructor to best match their preference, schedule, and practicality for the purpose of increasing participation and to include instructors in the research decisions (Pope, 2020). The online, pre-survey instrument was administered either synchronously during class or asynchronously, again in consultation with each instructor. The surveys were housed on Qualtrics, with question settings that requested, but did not require, answers to every question.

Survey questions were comprised of the TEQ, TROPOS, and EIS (described below) totaling 75 modified 4- or 5-point Likert-scale prompts plus 7 demographic questions (name, school ID, age, major/minor, gender, race or ethnicity, and classification) (Appendix E). Student participants took an average of 11.5 minutes to take the compiled survey (n = 493, after removing obvious time durations that indicated an extended dormant login to the survey software).

Participating instructors used their existing methods to teach ecology concepts to their students, without experimental intervention. I describe the types of teaching and assignments that they used, collected in the qualitative portion of this study, in the results chapter of this dissertation. During the last week of their semester, students were again recruited to take the same survey on Qualtrics as a post-test, using the same methods as described for the pre-survey. Exceptions to this setup were Hazel's section, who had already covered ecology content by the time the research commenced; so, students took the combined survey instrument by mid-semester, just after covering ecology, and again during the last week of the semester. The other exception was Gabe's sections in which students took the surveys before and after ecology-based

assignments since no ecology lecture content was delivered. Students across all sections took the pre-post surveys between 29 and 43 days apart.

Transformative Experience Questionnaire. The TEQ was developed using mixed methods procedures, with middle and high school students as the target audience (Koskey et al., 2018). Phases included peer debriefing to develop questions, pilot testing the target audience, field testing a revised instrument, then validation of the revised instrument with middle school (n = 115) and high school (n = 81) students in the midwestern United States. The TEQ uses a 4-point Likert scale, and includes 27 prompts, that contain 9 prompts about each of the 3 subcomponents of TE. That is, there are nine questions about *motivated use*, *experiential value*, and *perception change,* respectively. Each rating scale category provides a distinct progression along the variable to indicate higher TE with higher scores, though the three components did not cluster in principal components analysis. The instrument is therefore a holistic measure of TE as a form of engagement with behavioral, cognitive, and affective dimensions. Koskey et al. (2018) confirmed the instrument's reliability ($\alpha = 0.96–0.98$ across items) even with wording changes for different science topics (e.g., properties of matter, genetics).

I modified each prompt in the TEQ to refer to the ecology context of this study. For instance, "In other courses, I notice examples of *ecology* concepts" and "I talk with others about *ecology* concepts just for the fun of it" (italics added for emphasis). I also edited prompt 13, which included the phrase "either in real life, in a magazine, or on TV" to "either in real life *or through media, like videos*" to reflect modern media usage by our participant age group.

For responses on the TEQ pre survey for this dissertation, I ran scale reliability analyses using Andrew Hayes' MATRIX procedure (Hayes & Coutts, 2020) in SPSS (version 30.0). For the 401 responses, reliability was found to be excellent ($\omega = .95$, $\alpha = .95$) with a factor 1 matrix

range of .466 (Appendix E, item 30) to .754 (Appendix E, item 33) and all positive correlations in the correlation matrix. Manual calculations of discrimination indices (DI) of each item on the TEQ pre survey revealed just 1 of the 27 items below the .2 DI threshold, with DI = .19.

TRansformative Outcomes and PrOcesses Scale. The TROPOS was developed by Cox (2021), also through several phases. His literature review revealed five main concepts for instrument subscales out of which he crafted 59 questions to submit to an expert panel for review of face validity. The resulting 42 items on a 5-point Likert scale were administered in a pilot study to 12 master's students in a public service management program. Reliability analyses of those data led to a 30-item instrument to field test with 119 graduates of that same master's program. The data from that field test were analyzed progressively with descriptive statistics, correlations between items, linear regression, and then exploratory factor analysis. The instrument was reliable ($\alpha = .88$), with three of the four categories (social support, criticality, and transformative outcomes) surpassing the $\alpha > .70$ threshold. An exploratory factor analysis revealed a 3-factor model that accounted for 42% of observed variance. The first factor (25% of variance) aligned with mostly items from transformative outcomes and criticality questions. The second factor (10%) contained primarily social support questions, and the third factor (7%) had mostly attitude toward uncertainty prompts.

I edited three questions of the TROPOS – both stem prompts to direct students to think about the statements in the context of learning about ecology in biology class and by adding "and the environment" to one rating statement (i.e., "I developed a greater sense of responsibility toward others and the environment") (Appendix E).

Scale reliability analyses were conducted on the TROPOS pre survey for this dissertation research using Andrew Hayes' MATRIX procedure (Hayes & Coutts, 2020) in SPSS (version

30.0). For the survey responses (n = 401), reliability was found to be very good (ω = .89, α = .89) with a factor 1 matrix range of .245 (Appendix E, item 50) to .608 (Appendix E, item 61). However, there were a few negative correlations in the correlation matrix mostly associated with items 50 and 55. Manual calculations of discrimination indices (DI) of each item on the TROPOS pre survey revealed 16 of the 29 items below the .2 DI threshold, though 8 of those 16 items were at DI = .18–.19.

Ecological Identity Scale. The EIS was developed by Walton and Jones (2018), also during a mixed methods instrument development project that included interviewing three focus groups of environmental leaders and one of undergraduates (phase 1), then building survey questions to give to 40 undergraduates for *a priori* power analyses (phase 2), before administering their 5-point Likert-scale instrument, along with other existing scales (ecological worldview and universal values), to 497 undergraduates (phase 3). Item and principal components analysis led them to cut their original 31 items to 18 (resulting in Cronbach's α = .91), before confirming convergent and divergent validity of the resulting instrument. Results showed evidence of unidimensionality with all 18 items loading strongly on their first principal component, explaining 41% of their item variance. They then rotated their component matrix to minimize cross loadings and identify any other score groupings. The seven prompts relating to sameness remained strongest, while five about differentiation grouped on a second component, and six prompts about the centrality of ecological identity to the participant grouped to a third component.

Data they collected also demonstrated that this conception of ecological identity influenced a range of environmental behaviors directly and indirectly through worldviews and social values, as measured by the other instruments included in their study. They describe their

final instrument as capturing identity across person, role, and group aspects. I modified four words across two prompts of the EIS for readability (e.g., from “How likely are you to discuss wildlife, nature or environmental issues with each of the following people?" to “I am likely to discuss wildlife, nature, or environmental issues with...”).

Using Andrew Hayes' MATRIX procedure (Hayes & Coutts, 2020) in SPSS (version 30.0) I conducted scale reliability analyses. Using the EIS pre-survey responses (n = 402), reliability was found to be very good (ω = .88, α = .87) with a factor 1 matrix range of .02 (Appendix E, item 7, a reverse-coded item) to .78 (Appendix E, item 5). However, there were several negative correlations in the correlation matrix with item 7. Manual calculations of discrimination indices (DI) of each item on the EIS pre survey revealed 4 of the 18 items below the .20 threshold for DI, though 2 had a DI of .19. Three of these low DI items were reverse-prompt questions, indicating some potential confusion for respondents.

A final source of quantitative data was counts of instructor use of transformative teaching. That is, the previously described qualitative data were quantitized and imported into the survey dataset to use in further analyses, as described below.

Quantitative Analyses

Of the 402 student respondents who completed the pre-survey and 310 who completed the post-survey, 262 were found to have completed both pre- and post-surveys. Likert responses on survey data were converted to numerical values, and two missing data points of the 41,394 total, were found: One on the TROPOS-pre survey from one respondent and one on a different TROPOS-post survey question from a different respondent. Missing data were imputed using the median of each respondent’s scores on the relevant TROPOS subscale (e.g., the median of the six of seven TROPOS-criticality subscale responses from that participant) (Appendix E).

Of the 262 pre-post matched respondents, 60 were students in Hazel's section, who took their first set of surveys directly after they completed the ecology unit of the course. They completed the surveys a second time five weeks later at the end of the semester. In this way, those students acted as a comparison group for the other 202 student respondents who followed a true pre-post survey pattern.

Normality and Outliers. Descriptive statistics were calculated in SPSS (version 30.0) on all three instrument's pre- and post-scores for the group of 60 and then separately for the group of 202 respondents. I reviewed group mean, median, standard deviation, interquartile range, skewness, and kurtosis to get a broader picture of the data and to identify potential outliers in the population sample. I then tested normality on difference scores of all three instruments since difference scores would be used in later path analyses. Finally, I examined descriptive statistics for outliers across all three instruments pre-post scores clustered by instructor and campus, since those data would be used in repeated measures ANOVAs. These rounds of testing for normality are further described below.

For Hazel's students, skewness and kurtosis for all three instruments' pre-post scores was under the conventional |2| threshold, though the Kolmogorov-Smirnov test of normality indicated TEQ-post (.13[60], p = .018) and TROPOS-post (.12[60], p = .033) may display nonnormality. Examination of boxplots for these scales revealed a couple potential extreme values on TEQ-post, for which raw data was examined. But no unusual patterns were observed, so I maintained data from all 60 responses for this comparator group (Table 3).

For pre-post data from the other sections (n = 202), the 6 sets were under |2| for skewness and kurtosis except TROPOS-pre (kurtosis = 2.77) and TEQ-post (kurtosis = 2.65). The Kolmogorov-Smirnov test for normality further indicated nonnormality for: TEQ-pre (.07[202],

p = .009), EIS-pre (.07[202], p = .018), TEQ-post (.09[202], p < .001), and TROPOS-post (.08[202], p = .008). Boxplots revealed a potentially extreme, low outlier on TROPOS-pre (respondent ID 421) and potential outliers on TEQ-post (respondent IDs 330, 355, and 409). On closer examination of the raw data, #421 appears to have selected many of the same responses in a row on both pre- and post-surveys, even when reverse coded, and completed the survey in only 4.6 minutes. So, that case was removed from the dataset (Gabe's section). For #330, raw data for post-survey shows many of the same responses in a row, so post-survey data from that respondent was deleted from the dataset (Gabe's student). Numbers 355 and 409 appeared normal (no technical errors, and apparent variation in responses), so they were left in the dataset. While examining those data, #424 was found to have also had strings of the same answers on post-surveys and a response time of only 3.2 minutes, so their post-survey responses were removed from the dataset (Ava's student). This left 201 responses on the pre-survey and 199 on the post-survey which now indicated no signs of skewness or kurtosis (Table 3) for use in paired t-test analyses.

Difference scores were calculated by subtracting pre-survey scores from post-survey scores on each of the three surveys for the remaining 259 pre-post matched respondents to add to the dataset as new variables for use in later path analysis (e.g., TEQ-post minus TEQ-pre = TEQdiff). Descriptives were calculated on these difference scores, separately for the comparison group (n = 60) and the responses from the other sections (n = 199). For the comparison group, skewness and kurtosis were under the conventional |2| threshold for TROPOSdiff and EISdiff, while for TEQdiff skewness was under |2| but kurtosis indicated a leptokurtic distribution of 2.64 (Table 3). The Kolmogorov-Smirnov test of normality indicated potential deviance from normality for both TEQdiff (.14[60], p = .005) and TROPOSdiff (.12[60], p = .025). Visually

examining the data on QQ plots and box plots revealed one potential outlier distant from the QQ expected normal lines and outside the whiskers of the box plots for the TEQdiff data. Raw data for that response (respondent ID 190) was checked, and no technical errors or unusual response trends were found, so I moved forward with the 60 responses as valid, using a more liberal standard for kurtosis of |3| (Hahs-Vaughn & Lomax, 2020) (Table 3).

Table 3

Test for Normality of Student Survey Responses with Outliers Removed

Category	n	M	SD	Median	IQR	Skewness	Kurtosis
Hazel Section							
TEQ-pre	60	2.63	.05	2.63	.60	.004	0.63
TEQ-post	60	2.69	.07	2.80	.55	-.94	1.80
TEQdiff	60	0.07	.04	0.11	.32	-.69	2.64
TROPOS-pre	60	3.42	.05	3.45	.51	-.36	0.38
TROPOS-post	60	3.53	.06	3.47	.45	.62	0.37
TROPOSdiff	60	0.10	.04	0.05	.38	.05	0.80
EIS-pre	60	3.39	.07	3.33	.75	.29	-0.17
EIS-post	60	3.46	.06	3.42	.64	-.22	0.04
EISdiff	60	0.06	.04	0.06	.39	-.78	1.79
Other Sections							
TEQ-pre	199	2.50	.03	2.52	.52	-.69	1.15
TEQ-post	199	2.73	.03	2.74	.52	-.60	2.73
TEQdiff	199	0.23	.03	0.15	.41	.90	1.63
TROPOS-pre	199	3.45	.03	3.45	.48	-.25	0.17
TROPOS-post	199	3.57	.03	3.62	.52	.09	0.39
TROPOSdiff	199	0.12	.02	0.10	.41	.39	1.37
EIS-pre	199	3.42	.04	3.33	.78	.23	-0.14
EIS-post	199	3.51	.04	3.44	.72	.10	0.23
EISdiff	199	0.09	.02	0.11	.39	.18	2.13

Note. TEQdiff = TEQ-post minus TEQ-pre scores; TROPOSdiff = TROPOS-post minus TROPOS-pre scores; EISdiff = EIS-post minus EIS-pre scores.

The examination of the difference scores from the other 199 respondents took place next.

All three scales showed normal skewness, and both TEQdiff and TROPOSdiff showed normal kurtosis, using the conventional |2| threshold. The EISdiff data showed evidence of being leptokurtotic (2.13, SE = .34). The Kolmogorov-Smirnov omnibus test of normality indicated nonnormality for all three: TEQdiff, .13(199), $p < .001$; TROPOSdiff, .09(199), $p = .001$; and EISdiff, .09(199), $p = .001$. No extreme outliers were identified using QQ and box plots, so despite the indication of leptokurtic distribution for EISdiff, prior examination of raw response data, the kurtosis value close to |2|, and a sufficient sample size warranted moving forward with use of these difference scores in path analysis.

Finally, as repeated measures ANOVAs were planned, I examined normality of data by non-Hazel instructor and campus. For the 199 respondents grouped across the 6 non-Hazel instructors, indications of non-normality appeared on the TEQ-pre data for Sam (kurtosis = -2.04, SE = 1.23); the TEQ-post data for Lucas (skewness = -2.43, SE = .43; kurtosis = 9.61, SE = .83), Sam (kurtosis = 2.72, SE = 1.23), Maggie (kurtosis = 2.56, SE = 1.19), and Gabe (kurtosis = 2.60, SE = .66); and the TROPOS-post data for Lucas (kurtosis = 2.76, SE = .83). As Jack had only two pre-post matched respondents, no skew or kurtosis could be calculated. The Kolmogorov-Smirnov test of normality indicated nonnormal distributions for Sam's TEQ-pre data (.25[12], $p = .046$); Ava on EIS-pre data (.10[91], $p = .017$); Ava (.10[91], $p = .029$), Lucas (.18[30], $p = .019$), and Sam (.26[12], $p = .030$) on the TEQ-post; and Ava on the TROPOS-post (.09[91], $p = .047$) and EIS-post (.09[91], $p = .048$). A review of the histogram, QQ and box plots indicated extreme outliers on TEQ-post for Lucas (respondent ID 256) and Sam (respondent ID 145). Looking more closely at the raw survey data for #256 did not reveal any technical errors or invalid information, but #145 revealed long strings of the same answers during post-surveys. Respondent 145's post-survey data was deleted for further analyses.

The remaining 198 pre-post matched responses from the 6 instructors' sections were examined again for normality by instructor, which now revealed no signs of skew or kurtosis for any instructor on TEQ-pre. Since only data from Sam's student was removed, results for Lucas, Maggie, and Gabe remained the same as the prior analyses; Sam's TEQ-post data now revealed a more leptokurtic distribution (3.81, SE = 1.28). Analyses proceeded for the repeated measures ANOVAs with these 198 responses, but with caution in interpretation of results.

Descriptive statistics of data on the three instruments by campus then proceeded for these 198 respondents. Since campus 2 only had two students, no normality data were reported for that campus. TEQ-post was the only scale that showed values outside |2| for kurtosis for campus 1 (2.94, SE = .44) and campus 3 (3.05, SE = .55). Histogram, QQ, and box plots were examined for extreme outliers and four were identified: Respondent IDs 355 and 256 at campus 1 and 316 and 409 at campus 3. Raw response data for each was examined and no technical or response pattern issues were identified, so responses were maintained in the dataset with caution in interpretation of results.

Comparison Analyses. Paired sample t-tests on each of the three surveys' pre-post scores for Hazel's students were carried out in IBM SPSS (version 30.0) to look for any significant changes in scores on each instrument over time. I expected no change in Hazel's student scores since they took post1-post2 surveys, so I used one-tailed results from the statistical output. I then ran paired sample t-tests on each of the three surveys' pre-post scores for the combined non-Hazel sections to get initial results and an overview of score changes across all instructors and campuses by time, prior to further analyses.

Building up from those initial analyses, I proceeded to analyze the data from student respondents from the pre-post matched sections (non-Hazel students, n = 199) using one-within,

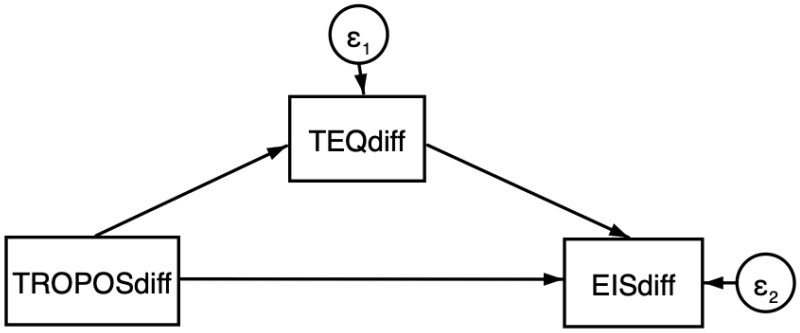
one-between repeated measures analyses of variances (mixed ANOVAs) by instructor and state. Since I had collected pre-post (two time points) scores, this method allowed me to better account for individual differences between participants and gave me a more precise assessment of interaction effects than using ANOVA or paired-sample t-test on difference scores. Time (pre-post) served as the within factor and instructor or state as the between factor since I was ultimately interested in not just the baseline data about change in students' transformative and identity outcomes but also differences by instructor and campus/state. Because campus 2 had only 2 student participants, running analyses by campus was not undertaken, relying instead on repeated-measures ANOVA results by state with those 2 participants filtered out.

Regression and SEM. I ran a simple linear regression in IBM SPSS (version 30.0). to determine if TEQdiff was a significant predictor of TROPOSdiff, then followed up with a multiple linear regression examining if the TROPOSdiff and TEQdiff scores were significant predictors of the EISdiff scores.

To continue to answer the question about the relationships between the three constructs, assuming significance of the regressions mentioned above, a structural equation model was estimated (STATA/SE, version 18.0) to examine fit of the data, using change in TROPOS scores (TROPOSdiff) as a predictor of change in EIS scores (EISdiff) as mediated by change in TEQ scores (TEQdiff). That is, I was exploring in what ways student shifts in TE and TL interact to impact the change in students' ecological identities (Figure 6).

Figure 6

Model of the Change in Transformative Experience Mediating the Relationship between Transformative Learning and Ecological Identity Shifts



Note. TEQdiff = Transformative Experience Questionnaire difference scores; TROPOSdiff = TRansformative Outcomes and PrOcesses Scale difference scores; EISdiff = Ecological Identity Scale difference scores.

Quantitative Analyses of Thematic Data. After separate analyses of those qualitative and quantitative data, the qualitative data was quantitized using counts of the identity and transformative teaching subcomponent coding (Figure 4). Analyses were then run to answer research question 2 about the relationship between instructor transformative teaching and student shifts in transformative experience, transformative learning, and ecological identity. This convergent design was meant to provide a more holistic picture of the impacts of transformative teaching on student transformative outcomes in my select cases.

The counts of identity, transformative experience, and transformative learning focus or goals collected from observations, interviews, and document analysis were used to calculate z-scores for each. These z-scores were examined to assign each instructor a level of high, medium, or low at breakpoints of .6 and -.6 to use in further calculations. These breakpoints were chosen by looking for gaps between z-scores or groupings of instructors that would categorize at least

one instructor section in each level. Overall instructor transformative teaching was calculated by summing the counts of identity, TE, and TL subcomponents by instructor that were derived from observations, mentions in interviews, and document analysis. Z-scores were again calculated from this overall amount of transformative teaching to assign each instructor a level of high, medium, or low at the same breakpoints of .6 and -.6 to use in further calculations. These breakpoints were chosen by looking for gaps between z-scores and groupings of instructors that would categorize two sections in each level. These four new level variables (by ID, TE, TL, and overall transformative teaching) were added to the quantitative dataset to use for analyses.

These new variables were used to answer my research question 2 about the predictive power of transformative teaching on student shifts in the three constructs using a repeated measures ANOVAs with time (pre-post) as the within factor and instructor transformative teaching level as the between factor. Analyses were carried out in IBM SPSS (version 30.0). These one within, one between type repeated measures ANOVAs (mixed ANOVA) provided a way for me to look at the main effects of time (did scores change post versus pre-test?), the interaction effects of time by instructor transformative teaching level (for TE, TL, and the ID-TE-TL compilation score), and pairwise comparisons of the different groups to look for trends.

Chapter 4: Results

Following the methods outlined above, I describe here the results of my analyses to help answer my three research questions about the nature of transformative teaching in nonmajors introductory biology; the relationship between transformative teaching and student shifts in TE, TL, and ecological identity; and whether TE shifts mediate the relationship between TL shifts and ecological identity shifts. I give qualitative results first, then quantitative summaries, including results from the integration of the quantitized qualitative data. In chapter 5, I discuss the implications of these findings.

Qualitative Results

Instructor interviews yielded the richest information about the collective, and each instructor's, goals and strategies in these select cases of nonmajors introductory biology teaching in ecology. This was due to targeted questions towards gathering data about transformative teaching (Appendix B). Observations and documents helped verify instructor comments, provided additional data, and gave a sense of context in each classroom environment. Beyond instructors mentioning the importance of ecology content understanding and skill-building, there was evidence across my sample of instructional methods that were employed to reach other goals. These methods included group discussions, out-of-class assignments, simulations, visual models, and stories that were employed to help instructors meet student outcomes of awareness or realization, seeing everyday topics in a new light, application of ecology concepts to other areas, affective shifts, and action.

I saw evidence of instructors considering identity, TE, and TL subcomponents for students in their nonmajor introductory biology courses. For example, in response to my broad interview question about their goals for their students completing the ecology unit of the course,

Maggie said:

> I am hoping that they can take an honest look at their own lives and the lives of people around them and a global perspective of people in different countries and understand our use of resources on the planet; and then, be able to take that information and make informed decisions later in life, when they're voting on things, when they're making personal decisions about what types of things they want to buy, what they teach their children about, what their responsibilities towards the world are, et cetera.

Summarizing the main learning outcomes of the instructors, for what they would like their students to be able to do, not just what they should know, they used the words "awareness," "realization," "appreciate," and connecting or relating ecology to their everyday lives or decision-making. Jack said, "...making them more confident when they speak in any environment about biology [ecology]." Having these outcomes of beyond-content understanding or skill-building were important precursors to being able to see evidence of other instructional goals such as identity, behavioral, motivational, value, perception, or perspective shifts, and instructional techniques like building everyday relevance of concepts, critical reflection, and critical dialogue.

Deductive coding of the qualitative data for evidence of identity, TE, and TL components (Appendix D) showed that each was present across this sample. Sample quotes typifying each subcode are provided in Table 4 and show the spread across instructors, modalities (Jack taught online), and data sources (interviews, observations, and documents). Within-case results are provided in more detail in narrative form below.

Table 4

Examples of Instructor Quotes and Teaching Observations by Deductive Code Categories

Data	Source	Code
"...one of the questions I asked them, I say, 'Now that we're talking about humans and what humans do, do you think you're part of this, or do you think you're outside of this?'" (Maggie)	Interview	Nature Identity
"... I have them do optional bonus assignments, where I basically tailor-created a list of articles or blogs or YouTube videos, highlighting the intersection of various facets of identity with STEM participation and equity..." (Ava)	Interview	Science Identity
"As Americans, we are heavy over-consumers. Likely, we never put thought into how our actions affect the environment. The goal of this activity [Global Human Impact assignment] is to increase your environmental awareness and to estimate what your individual impact is on the environment." (Gabe)	Document	TE: Motivated Use
"... they're learning about some of this stuff [ecology concepts] for the first time. They're like, '...[I] never thought about the food web that way,' or 'I never thought about the role an organism plays in its ecosystem.'" (Sam)	Interview	TE: Changed Perception
"Hopefully, some of that stuff is sticking. At least if they can't translate it very well, maybe it'll be a nice conversation piece with their friends or other colleagues." (Sam)	Interview	TE: Experiential Value
"...there's no way that we can mitigate global climate change, and now it's just how are we going to deal with it. I think that can be pretty surprising and uncomfortable and off putting for a lot of them." (Lucas)	Interview	TL: Disorientation / Awe
Some of the optional prompts for students' final video posts of the semester ask them to reflect on their expanded perspective on the value of science, their appreciation of the natural world, or their identity as a scientifically literate citizen. (Jack)	Observation	TL: Critical Reflection
"... encouraging them to learn healthy discussion skills, and critical discussion skills, I think is really important. So, one of the first things that I do, literally first day of class, is we talk about class culture expectations." (Ava)	Interview	TL: Critical Dialogue
"I think that, before, [it - environmental issues] was some adult problem that they didn't think that they had any say in. At least that's kind of the feedback I'm getting. 'Oh, these are choices I can make. It's not choices my parents have to make for me!'" (Maggie)	Interview	TL: Outcome / Expanded Perspective

Note. TE = transformative experience; TL = transformative learning

Case by Case

Hazel. The sole source of data for Hazel's teaching came from our one-on-one interview over Zoom, since she had already completed her ecology unit by the time this study commenced. She indicated that an overarching goal throughout her course is to help students make connections – both between course concepts and outside of class. In particular, she said, "So I really try and make a lot of connections in my class, but I think ecology is one of the more important ones.... So, like drawing all of those different connections within the content and within their lives."

> Hazel indicated that she shares her own stories of connections with students:
>
> So, like, when we were talking about over-harvesting, I mentioned that, you know, fish sticks used to be the thing that everybody ate because it was, you know, Atlantic cod. You could have them. And so, when I was young, like, everybody had Atlantic cod fish sticks, but you don't see them anymore.

In addition, she leaves space for and encourages students to share where they have seen ecology concepts in their everyday lives through their discussion board posts. "I mean, a lot of times the questions that they have are relevant to their everyday lives – just also kind of related to lecture." Together those sharing of noticing ecology concepts in everyday life and encouraging students to see and share their examples indicate the presence of *TE motivated use* (i.e., noticing) in Hazel's goals and teaching.

Another aspect that was apparent in Hazel's responses was *TE changed perception*. One ecology assignment has them, "talking about the OneHealth approach and thinking about how ecology can affect disease and disease spread. Specifically thinking about, like zoonotic diseases and other diseases that would be affected by human-animal-environment interactions." A class

discussion that she mentioned having was about "invasive species – We talked about how...some of them are like pet species that people have put out there. So, we have a question about, like, thinking about the effects of releasing pets into the environment." That is, Hazel would like her students to change their perception about the usefulness of ecology concepts (population dynamics and invasive species, in these cases) to inform important topics like human disease.

TE experiential value was mentioned the least of the TE subcomponents but was still present in the coding of Hazel's responses. She indicated that for the final product of one of their lab assignments (a community science project collecting data on birds), students respond to the prompt, "What are you going to gain from this project? You know, what kinds of skills?" And again, during an in-class discussion about their own ecological footprints (an assignment they are given) and overharvesting, she "show[s] them like, here's, you know, the Monterey Bay website where you can go and see: these are the good versus the overharvested [fish to buy or not buy]." That is, she both desires for her students to value ecology concepts in their everyday lives and gives specific prompts and resources to help them make that connection.

During this same interview, Hazel also mentioned phrases that were coded as *TL disorientation/awe, critical dialogue,* and one instance of *TL outcome*. Missing from her responses was *critical reflection.* She mentioned the use of stories and videos that introduce ecology content that may surprise or upset (i.e., disorient) students.

> I showed a little short video about horseshoe crabs and how they're used in the medical industry. I don't think most of them may have known that horseshoe crabs existed, but I don't think any of them knew that they were used by the medical industry.

In the context of the interview, and Hazel's description of how she uses that video in class, the goal was not for students to understand that horseshoe crabs existed or that they are used in

medical research, but rather to reach a deeper goal. Hazel was aiming to perturb students' thinking about the diversity of adaptations across life forms (a primitive creature that has blue blood) and about our use of other organisms for our own advancements.

As Hazel had mentioned during several other responses, the students' work in their linked lab sections of this course provided a rich context in which to provide impactful learning. Because of the smaller class size, that is where she integrates more active learning, group work, and discussion-based practices. To encourage the possibility of critical dialogue, beyond discussion board posts mentioned previously, Hazel stated that "when we assign lab groups, I always tell the TAs to assign as diverse of lab groups as possible." This diversity brings with it a diversity of opinions and backgrounds that are more likely to encourage critical dialogue.

Hazel indicated a goal for her students to have not just a changed perception about a particular ecology concept but an expanded perception (TL outcome) about what a scientist can look like. In her remarks on this topic, she mentioned both the construct of identity (science identity) and transformative learning (expanded perception about who is or can be a scientist). By having students collect data for their lab, community science (e-Bird) project, she is confronting them with, "Oh, well, actually, your conception of a scientist is very limited. All sorts of people are scientists, right?"

Ava. Both observations and interviews provided data on the sorts of transformative goals and teaching that Ava employed. Her interview data included codes across all nine subcomponents while observations yielded four of the subcomponents. In Ava's own words for her learning outcomes her students would have if completing the ecology unit:

> I hope that they can assess claims that they hear about ecological concepts in their day to day lives. I hope that they can relate what we learned in ecology to their individual

> decision making, as well as what they want to see for the country and the planet moving forward. And I hope that they can differentiate between ecologically-sound information and BS.

In other words, she wants the ecology content to have experiential value for the students, to shift their goals/motivations, and to give students the skill of scientific literacy.

With the introduction of each new ecology level Ava says, “We talk a lot about why we should study things. And when we talk about why we're bothering with population ecology or community ecology or global change ecology, I start out by always asking them what would motivate them in actually learning about this.” Ava is using a strategy to get her students thinking about their motivation to learn and the potential relevance that this information has on their everyday lives. This is an example of phrase that was coded as *TE motivated use.* She also shared her own stories of noticing ecology concepts in her everyday life.

> I have a pollinator garden out front.... And a neighbor of mine turned me into the city for a code violation.... I wrote an appeal because they said that I had noxious weeds. They claimed my cone flowers were thistles, which they're not.

This helped students see Ava’s motivation to use the concepts of diversity and taxonomy in her everyday life.

Ava desires for her students to have changed perceptions about ecology concepts, and she sees evidence of these shifts. “...a lot of them couldn't name a way that global warming was affecting them personally.... [So,] we have an entire unit on the human health implications of global warming.” Similarly, during the classroom observation, she told students “You are literally looking at stored CO_2 when you’re looking at tree trunks” and went on to remind them that burning wood releases CO2 into the atmosphere. In this particular case, she wanted her

students to have a shifted perception of global carbon cycles and their impacts on it.

TE experiential value was also evident in Ava's interview responses and classroom observations. She describes that:

> At the end of our global warming unit, when we were talking about the, what do you do about it bit, where we relate in, like, changing in your eating habits to lowering your carbon footprint and stuff like that. The thing that I think that I hit home with a personal story is the ability to do something about it in an ecologically intelligent way.

In lecture, she modeled how her knowing of ecology concepts helped her understand news stories and data that she came across. While covering climate change and carbon cycles, she mentioned that forests are good at storing carbon (carbon sinks), but that we are changing forest ecosystems which contributes to climate issues.

Disorientation and awe, as part of the process of TL, was evident in both sources of data from Ava. In referring to her personal story of her pollinator garden, she was modeling an experience that was disorienting to her – trying to do the right thing ecologically but coming up against a larger issue she had not considered.

> Okay, here's a problem, here's a solution at an individual level, right? Plants pollinator garden. But then what do you do when the structural system becomes problematic? And I think that that's where you get big enough that most people, me included in a lot of ways, say, well, there's nothing I can do.

She promotes the students' own disorientation, for the goal of them critically reflecting on and discussing their own perspectives, through narrative story and surprising facts. In class, I observed her telling the students that "most of the CO_2 causing global warming (53.4%) was put into the atmosphere since 1991" and that "some breaks down after 30 years, but most will still be

there after we die." She is driving them to confront humanity's role in climate change.

Importantly, Ava supports students in that liminal space of disorientation by prompting them to critically reflect. For instance, after watching a film about three women in different parts of the world impacted directly by climate change, she "asked them to think about how the women felt when they were experiencing those changes. And then I asked them, 'Have you ever felt that way in a situation like this?'" She is again using human stories and this time having students reflect on affective components and their own sense of powerlessness in certain situations.

To further support students, she explicitly sets up expectations for group interactions and dialogue – whether it be content discussion, opinion justification, or critical dialogue.

> So, encouraging them to learn healthy discussion skills, and critical discussion skills, I think is really important. So, one of the first things that I do, literally first day of class, is we talk about class culture expectations. So, we talk about how science is learned by doing and how it's going to be an incredibly active class, and that's going to necessitate them being participatory. And you know, I set up basically a code of respect for them to one another, me to them, them to me, and just basically reinforce the idea that we are all mutually deserving of respect and that I'm always going to treat them that way.... I instruct them to find somebody who answered differently than them [on in-class on-screen questions]. And I tell them to give each other their arguments and poke holes in one another's arguments using evidence from the slides to make their point if they think their partner's argument was weaker.

This expectation and culture of healthy discussion sets up an environment through which students could dialogue about their critical reflections emerging from their disorienting

dilemmas.

TL outcomes were shared by Ava when telling her students about her expanded perspective of herself as empowered, civically engaged, and a change-maker during her pollinator garden, city appeal process.

> And so, I wanted to remind them that you don't actually have to be an expert in [something] to affect positive change; and that I know literally nothing about the law, but all I had to do was shoot off a whole bunch of emails to knowledgeable partner groups and, bam! You can get it going.

This theme of empowerment as a type of TL outcome showed up again in Ava's description of one of her final discussions in her ecology unit. "Now you have actual tools for implementing broader social change..., because if you've ever been scared or worried or sad, and you don't want to see that in other people, here are some actual tools to alleviate that suffering."

During the interview with Ava, she noted that she talks to her students about where her interest in ecology emerged from - "falling in love with a place and therefore, wanting to know more about it." In telling her story of connection to nature, she describes her own feelings of being part of the ecosystem where she grew up, and therefore a type of nature identity. Though that was her only mention of nature identity, she mentioned an assignment, a bonus assignment, and a class discussion with the goal of reflecting on science identity. During their community science project, she:

> ...asks them to reflect on what a scientist looks like...and they do it by looking at drawings that these kids have done before and after they went to some physics lab.... They look at the differences between the kids' pre and post drawings, and we have a discussion for them about why they visualize scientists the way they do, and part of that

is led in lab, and I ask them to think about you know, what their group visualized. Data from Ava displays strong evidence that her goals include beyond-content transformative shifts in her students and that her teaching methods include aspects of TE, TL, and identity.

Lucas. The third instructor at campus 1, Lucas, showed evidence of goals or inclusion of ecology teaching strategies in all three constructs. Compared to his two colleagues, he focused less on identity and more on TE components. He warned that, "I spend a ton of time at the cellular level. And then..., I try to just give them a quick crash course through the organismal-ecology-evolution stuff." Despite that, his goals for his students completing those two weeks of ecology content are:

> ...appreciating more of the world around them..., the biology that the student sees day in and day out; whether or not they recognize and notice it, how it pertains to their person. But I mean, just having a little bit more of an awareness of everything that's going on around them and how the choices that we as society make, and they as individuals make, will ultimately impact you know, impact biology at large.... [I'm] trying to get them to see and think big picture.

Lucas described an example of a conversation with a student who had been thinking about energy use to heat water during teeth-brushing – energy which could have been created with fossil fuels that released harmful greenhouse gases. They had a discussion about leaving the water running or not, and whether it mattered if it was cold or hot water. "I'm not responsible now for the energy to heat the water, which is just going to be lost, but still if you're leaving the sink running, now you're still losing that water that has to go through water treatment" [which takes energy]. The student was motivated to apply a course concept to her everyday life. During my observation of Lucas, he also described his noticing the concept of population and population

density by naming the population size of students in the room compared to the density it might be in New York City.

By both giving an example of his changed perceptions, and in his teaching strategies to help students shift their perceptions, Lucas displays this aspect of TE. In speaking about their community science e-bird project from their linked lab section, he says:

> I've become a little bit more aware as to how wildlife impacts us, you know, diving in and learning more myself before teaching it to the students about, you know, like ecosystem services.... I share with them how my eyes have been opened a little bit more about the e-bird project.

To help students start to change their own perceptions about the usefulness of ecology concepts, Lucas shares lots of examples from everyday life – weeds as invasive species in a whole community of different plant species, your dog having puppies continuously would add to the population and population density in a house/yard, or a mudslide happening in California splitting a the habitat of a population of organisms in two. Those were all shared during the classroom observation of Lucas.

One of Lucas' goals for his students relates to *TE experiential value*: "I just hope that they have a little bit more of an awareness, and they're taking an extra beat before they make certain choices or make certain decisions." One of the ways he tries to reach that outcome is through the e-birds assignment previously mentioned. As a final product for that assignment,

> ...we have them draw their conclusions and most importantly, then, communicate to the non-scientific audience. And their piece of media is supposed to explain to their nonscientific audience what [they did] in the project. Why did we spend some time doing it? Why is it so important? And why should this audience care?

To disorient or give students a sense of awe during the ecology unit, Lucas says that he talks to his students about climate change:

> ...the scientific community now has pretty much agreed that there's no way that we can mitigate global climate change, and now it's just how are we going to deal with it. I think that can be pretty surprising and uncomfortable and off-putting for a lot of them.

In addition, they have an assignment that he hopes opens their eyes. “So, this ecological footprint, they're always blown away with.... So, I think that one is probably the biggest eye opener. Um, I hope that it is.” Other topics that may upset them are, “Yeah, the population growth is surprising. Extinction rates can be surprising to them."

During the observation of Lucas, no opportunities for student critical reflection on their assumptions or worldviews were noted, though he mentioned a couple during the interview. After an activity in class of watching a documentary called *Chasing Coral,* he leads a discussion with them about the destruction of coral reefs and/or other ecosystems. “And now let's shed some light on understanding why those are bad things that we're doing. And here's what have we tried? In human history, what have we done?” Similarly, students in Lucas’ section do not appear to be given much opportunity for critical dialogue. None were observed, though in the interview he did mention setting up a classroom and lab environment where students were comfortable discussing topics. “I try to get students talking with one another as much as I can. I think you know that peer-to-peer conversation, arguing, debate is very good and very healthy.” For lab groups, since they have some stability and can have some diversity, he sees that as an even richer environment for dialogue. “So those different backgrounds and strengths and weaknesses and aspirations, that that can really produce some good, holistic, fruitful discussion. Again, maybe some maybe argumentative here and there and that's okay as long as it's still respectful.”

A *TL outcome* that Lucas discussed in his interview was students' expanded perspective about the power they have to improve their own ecological footprint and the power of collective action. "Change just this little thing, and what does that do for you? And if everybody does something similar, changes that little thing, we can see some real significant impact." More broadly for the ecology unit, he indicated that he wanted students to have an expanded perspective about the connection between living things. "And really that's the spirit of ecology, right? The interactions between all these things." Lucas reflected on the importance of identity formation in his students: "They are developing their own thoughts on society and legislation and religion and philosophy and who they are as people," but did not indicate a goal of helping them in that identity formation or connecting their identity to ecology or nature. He did, however, mention that he hopes his students think of themselves as scientifically-literate by the end of the semester. This came close to the identity construct, though it was separated from both scientific and nature-based identities.

To summarize, Lucas' main goal for his students in completing the ecology unit of his course is that they have increased awareness. As such, the teaching methods that he mentioned and that I observed were aligned with the TE construct more than TL or identity.

Jack. Jack was the sole participant at campus 2 and taught an asynchronous, online course. Data collection consisted of a Zoom "tour" of the ecology unit of the course in the learning management system (observation + documents) during which time I also asked him some of the semi-structured interview questions. For Jack, "Generalizing the major goal of the whole class – making them more confident when they speak in any environment about biology. But in the specific part of ecology – ...explaining this concept and being familiar on defining the specific things about ecology." Stated differently, he wants them to be able to "establish a

conversation using the basic scientific language about this environment that they may be in, just in the professional environment and the daily life environment."

TE motived use did not come up during the course/document tour, but Jack did mention it during responses to interview questions. One of the assignments students submit is a video *Starting Assumptions* to start the new weekly topic in response to one or more of several provided reflection questions. Jack stated that he has seen about a third of his students say on the discussion board, "So, I've been, after this class, I've been reading more in detail about this topic. And they put that in perspective how they got [what they thought] before and what they have now." That is, students are self-reporting that they are motivated to learn more about a topic through potentially intrinsic motivation.

The course tour/document analysis revealed assignments that sought to change students' perceptions of everyday experiences. One assignment option in their second week of the unit includes a pesticide analysis that asks students to investigate the ingredients of a pesticide they have/use at their residence, including publicly available information about harmful environmental impacts of it. This was categorized as *TE changed perception* because the goal seemed to be to change student perceptions on safety of household chemicals and/or the interconnectedness between species and how abiotic factors can impact ecological communities. Yet another optional assignment called "Environmental News" shows them that they can interpret everyday, and contemporary news clips/articles in light of ecology concepts. It seeks to change their perception of the usefulness of learning ecology.

Jack's use of *TE experiential value* was noted during both the course tour/document review and interview responses. The opening paragraph of this section on Jack indicated that Jack's main goal for his students is for them to find value in their everyday life in understanding

ecology. Part of how he promotes this is in the list of potential prompts they can answer in their Starting Assumptions video posts each week. For instance, during the first week of the ecology unit, some of the prompts he gives students related to experiential value include: “What do you think about meatless meats as part of the solution to climate change?” and “Have you ever been to a rainforest? What do you remember about the plants, climate, or biodiversity?” These show students that knowledge of ecology concepts can prepare them for conversations in everyday life.

He states this experiential value goal again when asked about activities that might cause them to reflect on their identities as ecologically literate citizens or as part of nature:

> I don’t have any specific assignment..., but I think that the chapter about climate change... [gives] them those few tools that they can actually perceive/measure real world data that they can use to measure the impact of climate change is probably something that will make them feel confident to talk about that topic than they were before taking this class. Instead of identity, they probably will be more confident to talk about, in the scenario that is probably daily life scenario about climate change and the issues that climate change can cause on the planet.

Neither nature-based nor science identity were noted in Jack’s goals for students or course activities that he provides them.

TL goals and language were seen minimally in Jack’s interview responses but were noted more often during the course tour/document review. In review of the course documents, I noted that for the *Starting Assumptions* prompts that Jack provides students in week 2 of the ecology unit, some present facts or bring up topics to disorient students or illicit awe. For instance: “Had you heard of China’s one-child policy? How would a policy like that work in the U.S.?” and his invitation for students to look at Peter Menzel’s photos of families from different parts of the

world surrounded by all their possessions, followed by the prompt, “Do these types of images inspire in emotions in you?” Like other instructors, he also uses the carbon footprint calculator to disorient students about their personal ecological impact.

As revealed during the course tour/document review, students are guided to some opportunities for *TL critical reflection* following those potentially disorienting prompts. By including the phrase “Why or why not” in several of his *Starting Assumptions* video post prompts, critical self-reflection could be happening there. The strongest evidence, though, is found in students’ end-semester video post prompts, which happen to also overlap with week 3 of their ecology content. It asks students to reflect on how the course may have “expanded your perspective on the value of science or your appreciation for the natural world.”

Jack described his discussion board assignments through which students are required to respond substantively to two or more of their classmates. For him, “Having this opportunity of them making comments on other people's point of view is something important.” By substantive, Jack explains that the goal of the responses, tied to course points for the assignments, is “to provide some good rationale for whether you agree, disagree or are not completely sure about that. But provide some context for that.” This does not mean that the discourse will always be critical dialogue, though critical thinking does seem likely. However, it sets up an online environment where critical dialogue is possible.

No *TL outcomes* were coded from Jack’s interview responses, but potential outcomes were noticed from the course tour/document review. For their carbon footprint activity in week 1, students submissions include an action plan about what they have or would like to change about their behaviors to positively impact their footprint. This is not a demonstration of changed behavior, just a plan, but could indicate a desire for the students to have an expanded perspective

on themselves as having the power to make an impact on this global challenge. Similarly, during their week 2 *Pesticide Analysis*, they are asked to include a response to the question: "Based on your use of the product and what you now know...do you feel confident that the product is safe to use? Explain why or why not." They could indicate that they have or will stop using the product (behavioral change) due to their expanded perspective about human and chemical impacts on the environment; but there is no way to verify that change.

Jack mentioned several times that many aspects of this online course were adopted from the previous instructor. That means that Jack's goals for his students may be discordant from the types of transformative assignments that are embedded. This appeared to be the case with many of the interview responses revealing goals of *experiential value* while some assignment goals appeared to be *expanded perspectives* along with *experiential value*. Overall, this case was especially useful in providing evidence that even in an online, nonmajors biology course, transformative goals and education were observed.

Sam. This first instructor results from campus 3 come from Sam. The interview and observations did not reveal any identity focus and only minimal evidence of TL; but both data sources provided evidence of TE components. This matched with Sam's response to the general interview question about his learning outcomes for students finishing the ecology unit of his course. "Hopefully some of that stuff is sticking; at least [even] if they can't translate it very well, maybe it'll be a nice conversation piece with their friends or other colleagues."

For his nonmajors, Sam says, "any kind of thing that they can pick up [about ecology] and take to their own fields of study, that would be great." That is, he wants them to be motivated to use ecology concepts in their everyday lives – to be able to transfer to their areas of interest. He modeled this during my observations of him during lecture by telling the students

about him noticing differences between the climate/weather where he grew up in the U.S. versus his couple of visits to Indonesia, which is closer to the equator. This was while introducing biogeography and the distribution of ecosystems due to the tilt of the earth. While introducing the concept of commensalism, he also mentioned seeing white birds (egrets) in a field of cattle in his everyday life. This modeling of *motivated use* could help students start looking for ecology concepts in their everyday lives.

An example that Sam shares with his students during his lecture on community interactions is that of gray wolves and elk in Yellowstone National Park. He notes that "typically, when they[students] think of wolves, they think, 'Oh, predator bad,' but it actually is good for population control, especially if a population like elk becomes a nuisance species, overgrazing its habitat and then causing wrecks with drivers." His goal is for students to have a different perception of predators and of predator-prey interactions. He describes that goal again in relation to students' perception of ecology as a whole:

> I think they come [into the ecology unit] thinking that it'll probably be a little bit easier than the previous section.... But then they learn about stuff like nested communities, and energy absorption, and the carbon, and the hydrologic cycles, and stuff like that, and transpiration, how all that water moves into system. So, it's a lot more complex than what they think.

The third component of TE, *experiential value*, is promoted with Sam's students through a reflection paper he assigns them "...talking about the relevance to their own life. Why is this important to you? What kind of pertinent information can you get out of this content? How's that going to affect your life moving out of this class?" During my observation of his teaching, he told students about seeing climate change in their own state and how weather is changing

differently in “our state versus weather on the equator.” Sam wants his students to see value in knowing ecology concepts and gives scenarios where they could find these concepts useful to know about in their everyday lives.

Sam described his use of disorientation or awe with his students through engaging biological stories he tells. For instance, after telling them about the pelagic sea slug that can prey on jellyfish and incorporate their stinging cells into their own tissues, “they’re like, 'Oh, wow, that’s wild.’” In class, I observed him telling students about the speed and power of the predation strike of the small, marine mantid shrimp. Both of these seem to hold the intent of not only catching students’ attention but disorienting their view of the complexity and specialization that evolution has brought to the biological world.

Sam did not indicate during the interview nor observations, that he incorporates any *TL critical reflections* or *TL critical dialogue* in his course. However, he did seem to desire certain transformative outcomes for his students during interview responses. Sam mentioned that in lab (not linked directly to the course), students do “a lot of hands-on stuff…where they can actually see, ‘Oh, this is really bad for the environment…. Why aren’t we implementing this [solution/behavior] more readily?’” He also mentioned he would like to:

> …get them more conscious of, yeah, how they act in the ecosystem; how they contribute to their environment, you know? Making sure they don't litter, you know, are conscious of, you know, wasting water or something like that. Every, even the most tiny, insignificant change, can actually lead up to something that results in a better, uh, advantage for the environment.

Student transformative outcomes needed to reach these goals include not just consciousness-raising but critical reflection that leads to behavioral shifts.

In summary, Sam mentioned some goals for his students that included both TE and TL outcomes, and some evidence of methods to reach those were apparent. During his interview, he also mentioned that this was the first semester he was teaching lecture, versus just lab, for nonmajors biology. He reflected that in future semesters he hoped to integrate more impactful and active learning into lectures to meet his desired student learning outcomes. This indicates his desire to have transformative impacts through classroom activities, though a self-realization that he has room to develop and integrate those further.

Maggie. During both the observation and interview responses, Maggie displayed or mentioned some aspects of TE, TL, and identity. She was able to clearly articulate her learning outcomes for the ecology unit of her course, and these included aspects of changed perception, experiential value, and expanded perspectives (that is, both TE and TL components). Here initial interview response encapsulates her perspective:

> I am hoping that they can take an honest look at their own lives and the lives of people around them and a global perspective of people in different countries and understand our use of resources on the planet, and then be able to take that information and make informed decisions later in life, when they're voting on things, when they're making personal decisions about what types of things they want to buy, what they teach their children about, what their responsibilities towards the world are, et cetera.

During her classroom teaching, Maggie modeled *motivated use* to her students. While talking about population growth, she told her personal story of hearing in 4th grade when there were 4 billion people on earth and realizing that we have now reached 8 billion people, displaying a doubling time of 8 billion years. During our interview, she gave several other examples of the types of personal stories she tells during class of being motivated to notice

ecology concepts in her everyday life. For instance, “when we talked about ecological isolating mechanisms…, I use the example of our turkeys as courtship displays and talk about how the turkeys do the turkey dance.” Maggie was further able to identify specific instances where her students displayed *motivated use* of ecology concepts. After she showed students a video about Pesto, the giant baby emperor penguin in the news recently, “They were bringing me updates on him for several weeks.” And in response to an ecological footprint assignment, where students calculate their carbon release, “many people went on and applied it to other people, because one of them was like, ‘I sat my roommate down and asked her these questions and typed it in, and we got similar answers!’”

TE changed perceptions came up several times in Maggie’s responses to interview questions. When talking about her food diary assignment, during which students record how many different species/types of plants or plant parts they eat over a couple of days, it was evident Maggie’s goal was for their perception of human-plant interactions to change. “I just thought it'd be fun, because we never think about what plants we are using. We always think about what animals we’re using. We never think about what plants we're using.” In her use of classroom discussions, Maggie explains that she tells the students, “I just want to know where you are and what you're thinking about it; and has what we've talked about today changed the way you think about it [an ecology concept] in any way?” This seemed like an obvious goal, and method, for Maggie to get at changed perceptions about ecology concepts (rather than expanded perspectives about the student’s own perspective or identity).

During class, Maggie introduced the mosquito-borne disease, Zika virus, to talk about population growth and community interactions. She explicitly stated that “If we understand mosquito population ecology, we could control them to decrease disease.” In so doing, she was

promoting her students seeing *experiential value* in understanding population ecology principles. She corroborated this student outcome of *experiential value* in her interview responses. As a follow up to their ecological footprint assignment, she frames the results and their responses by telling them, “This is going to affect you. I'm giving you the information you need to know to make the choices so that you create a world in which you want to live.” Speaking more broadly about the ecology unit, or even the class as a whole, Maggie tells her students that, “I've given you a place to go where, if you don't know the answer to something, you could find it.” She is explicitly pointing out the value of the class and ecology unit to the students’ everyday lives.

Maggie recalled her potential use of disorientation or awe as an on-ramp to TL in her ecology unit.

> I'll bring in a picture or a short video of an animal…that is right on the verge of extinction and that is upsetting to people. Especially when you start talking about, “They do this cool thing; they do this, they…Oh, by the way, there's only 150 of them left in the world.”

She is confronting students with their potential part in leading to that or other extinctions of whole species – their responsibility in correcting the injustice. Or even for our own species, I observed her in class driving home the point that in the next 40 years, when most of them are around 60 years old, or even earlier, the world population may hit 16 billion people – it depends on the choices they, and all humanity, make.

During class discussions, Maggie mentioned that she asks lots of critical reflection prompts to get her students thinking. On the heels of the ecological footprint results and during the content around climate change is one place she described this happening.

> One of the things that I try to get them to think about is, ‘Okay, so you're here, you're

> now, you're in the US. You obviously have a certain amount of resources available to you because you're sitting here in my college classroom. You're rich compared to the rest of the world, right? So how do you think that changes your responsibility versus somebody who was born in poverty in a third world country who doesn't even have access to clean water? Are your responsibilities towards making these [environmental] decisions the same or different?

More generally, she mentioned a critical reflection question that she has ready to ask during class discussions at various parts of the semester: "Well, does that change your assumptions about this whole system?" By asking them to think about their own assumptions and systemic structure, she is strongly aligning with TL processes.

For whole class discussions and for in-class activities that were planned this way, Maggie has her students participate in group activities at their tables (the room is set up with table pods with 4-6 people at each table). This gives an environment that could be more conducive to critical dialogue, because "everybody's bouncing ideas off of everybody, and they come to some consensus about what gets written down and what doesn't." Maggie further describes the group dynamics during class that could encourage critical dialogue:

> …95% of people that are coming to class and being engaged and participating are encouraging of everybody in their group to participate. And they spend the couple of moments that it takes to actually look at somebody and listen to what they're saying, which is really different. I'm really shocked by that. In fact, I tell them that a lot. I say…., "I'm really impressed by the way that you listen to everybody, and I'm really impressed by the way that you take everybody's opinion into consideration, even if you don't agree with it, and I'm very happy that you all are being respectful of each other," and I feed that

back to them a lot because I want them to do that.

TL outcomes by way of expanded perspectives were noted from Maggie's interview responses. After presenting students information about the diversity of reproductive models and fluid sex in the animal kingdom, she notes that "it challenges their views on how life works…. It just gives them, I think, it challenges their preconceived notions about what living things are and what living things do." As another example, Maggie describes what she has seen as a result of students' ecological footprint activity – their expansion of perspective of themselves as change-agents:

> I think, first of all, that they learned that there is something they can do. I think that before there was some adult problem that they didn't think that they had any say in. At least that's kind of the feedback I'm getting. 'Oh, these are choices I can make. It's not choices my parents have to make for me,' you know; I feel like that's a little bit of it.

She further drives this home by putting energy into helping them understand that they have "personal power in making some of the decisions that actually affect the bottom line" and that "their personal decisions can influence [the environment]; and that, en masse, they are pretty powerful."

Maggie's data included a couple references to identity. She mentioned hearing from two students that they were changing their majors to biology, "because they didn't know biology was interesting." This is clear evidence of an identity shift for those students, and it aligns with a role-based, science identity. However, Maggie also mentioned a question she asks during in-class discussions, "Now that we're talking about humans and what humans do, do you think you're [a] part of this, or do you think you're outside of this?" This is related to students' feelings of connection to ecosystems and the interconnectedness of our decisions and earth's cycles. This

indicates Maggie's desire for students to reflect on their nature identities.

Interview responses from Maggie revealed a strong desire for her students to find meaning in the ecology content to apply to their everyday decision-making. Further, she indicates goals for her students to think more deeply about ethics and their responsibilities towards ecological impacts. These are backed up with specific, reflective prompts that she was able to voice. The classroom observation revealed examples of how these prompts were used – sometimes as rhetorical questions which students may have chosen to not engage with and sometimes in small group activities where one or more students are required to respond.

Gabe. The final instructor case, and third instructor at campus 3, submitted interview responses via online survey and submitted three assignments that students turn in as their activities through which they learn ecology content (no ecology teaching was delivered or observed). Across these data sources, there was evidence of TE, TL, and identity, though instances were minimal. Gabe's overall goals for his students completing the ecology assignments included reference to TE components. He wants them to "Be aware of how science works and how science affects their everyday life…. And [that] personal actions taken affect all of us."

TE motivated use was coded for Gabe's responses in which he described his ecology assignments and in review of the documents themselves. For the *Pollinator Garden* assignment, students visit a campus pollinator garden – an outdoor space that may be, or could become, part of their everyday activities. While there, they are asked to identify any 10 plants and their likely pollinators. Since students are around plants in their normal life routines, this encourages them to notice other plants around them, even beyond the garden. In describing his *Course Reflection Writing Assignment* he tells students that "The goal of this written reflection is to apply

biological concepts to societal issues." He did not mention any stories he tells students to model his noticing of ecology concepts in everyday life. This could be because he does not deliver ecology content in lectures or through his course website.

"As a biologist, I impress upon the students that humans are only one species and a young one at that. Life is much more than being human-centric." This conveys Gabe's goal of students' *changed perceptions* about the diversity of life on earth and about the long timespan of ecological processes. Similarly, he seeks to motivate students to change their perceptions of how they impact their environment. This was seen in his *Global Human Impact* assignment where he informs students in the introduction that "As Americans, we are heavy over-consumers. Likely, we never put thought into how our actions affect the environment. The goal of this activity is to increase your environmental awareness and to estimate what your individual impact is on the environment."

Another stated goal of Gabe's *Global Human Impact* assignment is "to create awareness and offer easy tips on how to be more active in making smart consumer decisions." That is, he wants students to find experiential value in knowing what environmental consequences various actions may have (and how to mitigate those). This is also seen in the review of his *Pollinator Garden* activity in which he tells students that, "An overarching hope is that the garden will inspire visitors to use native plants in their home landscapes." Gabe's goals for nonmajors students during their ecology assignments is beyond learning content to giving them skills, a new perception about environmental impact, and for them to find value in the understanding of ecological processes.

The use of disorientation by Gabe, that could help jumpstart TL processes, was seen in one of the three assignments he referenced in his interview response. For the *Global Human*

Impact activity, he asks them to calculate their ecological footprint and then "take a screen shot of your household carbon footprint in how many trees you would need to plant yearly to offset your carbon output." He goes on to warn that, "The intention isn't to make you feel bad or guilty about your lifestyle." That is, he anticipates that this information about the number of trees they would need could be surprising or upsetting.

No *TL critical reflection* nor *critical dialogue* were noted as ways to help the students deal with this disorientation mentioned above. In fact, no dialogue was mentioned in any of Gabe's data. However, for their *Course Reflection Writing Assignment*, students are given a prompt to elicit critical reflection:

> Describe how learning about the topic changed your personal assumptions, habits or values, and how that changed your opinions and/or behaviors related to the topic. What assumptions or prior beliefs about the natural world did you question due to your learning about the topic?

For that same assignment, he also asks students to respond to "What behaviors, if any, did you change in response to your new learning?" This indicates that Gabe thinks a TL shift like behavioral change is possible, though the topic the students chooses could be from any part of the course, not just the ecology assignments. Gabe had not mentioned these prompts in his interview responses, so he may not have recognized them as the type of prompts that could lead to TL. Gabe's students are also asked, for their final reflection, to "Describe how learning about that topic challenged your understanding of how you interact with the natural world." Even though the students' topics could come from any part of the course, that prompt directly asks them to consider shifts in their nature-based identities.

Even without lecture content over ecology being delivered, Gabe allows us to see that

out-of-class assignments can be designed with transformative outcomes in mind. In Gabe's current setup, the important step of critical dialogue is missing, though other aspects of TE, TL, and identity are integrated.

Thematic Summary and Quantitized Results

Thematic Summary. Looking across the seven cases for cross-case analysis helps answer research question 1 about the nature of transformative teaching in the ecology unit of these select nonmajors biology courses. All seven instructors showed evidence of including the three subcomponents of TE in their goals and teaching practices. Implementation of TL components was more variable across instructors, and a specific focus on identity received the least attention. This aligns with Heddy & Pugh's argument (2015) that TE is more a more practical framework to integrate in a classroom than TL. Some instructors seemed to display better alignment between what they said their transformative student learning outcomes were and their practices as observed in-class or through assignment documents. Overall, all instructors had goals for nonmajors completing the ecology unit of their courses to have more ecological awareness, value understanding ecological principles, and be able to use these concepts to enhance their everyday lives.

Several instructors modeled how they notice ecology concepts in everyday life, an important component of Teaching for Transformative Experience in Science (TTES; Pugh, 2020). Most of them also explicitly pointed out where students might notice ecology concepts in their everyday lives and/or encouraged students to discover those places. Through storytelling, community science, and discussion-based learning, instructors sought to change students' perceptions about particular ecology concepts (e.g., human impact on ecosystems through greenhouse gases) or about ecology as a powerful field of study. Several instructors' overall

goals for their ecology unit involved experiential value by demonstrating practical applications of ecological knowledge in students' daily lives. This was accomplished through activities, like the ecological footprint calculator, reflective prompts posed for group discussion, and storytelling.

Among the observed TL components, most instructors deliberately incorporated disorienting dilemmas through assignments like the ecological footprint calculator, sharing alarming facts like extinction rates or human population doubling time, or by showing climate change data to challenge student assumptions. There was more variability in instructors' inclusion of either critical reflection or critical dialogue in their courses, which are both important aspects of the TL process (Cranton, 2016). Ava and Maggie, instructors from campuses 1 and 3 respectively, described robust opportunities for students to reflect on and discuss their assumptions, while others included minimal reflection opportunities. Interestingly, the online instructor, Jack, was observed to have the most robust experiences for potentially critical dialogue due to the course designs heavy use of discussion boards. Several instructors aimed for their students to expand their perspectives, particularly around them seeing themselves as empowered change-agents regarding environmental issues.

When identity was mentioned, it often focused on expanding students' perceptions of who can be a scientist (science identity) or less often on helping students see themselves as part of nature rather than separate from it (nature identity).

There were varying levels of alignment between what instructors said was their focus during interviews and what was observed in-class or through document analysis. Ava and Maggie showed the most consistency between their stated goals and observed practices. For example, Ava articulated clear transformative outcomes and demonstrated corresponding

teaching strategies in observations, with evidence across all nine subcomponents. Jack commented about his adoption of most course activities from a previous instructor, which could explain less mention of transformative goals during his interview, but higher instances during the course tour and document review.

Additional information emerged that was not explicitly sought from instructors but would be helpful to note for future studies. The number of years of experience (or semesters of teaching that course) could have an impact on both their inclusion of transformative methods and their alignment of course goals to course activities. Sam mentioned that this was his first semester teaching lecture and that he had goals to implement more impactful activities in future years. Ava mentioned that she had taught the course enough times that she knew the trends of what sort of misconceptions students would have and so could develop activities to help address those ahead of time.

Though information about a linked, required, or non-required biology laboratory was not explicitly collected, all three instructors from campus 1 (who have a lab section linked to the lecture section) mentioned it numerous times as a spot where many of the transformative activities might happen (e.g., group work, community science project, group discussions). Jack's online section did not have a lab available to students, and at campus 3, a separate lab was available that some students were enrolled in (and that Sam mentioned). Finally, as mentioned above, a closer examination of which outcomes and classroom activities the instructor created, adopted from elsewhere, or adapted from elsewhere could help explain the alignment or misalignment between goals and course activities offered to the students.

Quantitized Results. Interviews included questions about identity and were more targeted towards collecting responses for the subcomponents of the three constructs compared to

classroom observations and document review data collection techniques (Appendix B). TE categories were mentioned the most in instructor interview responses (191 times compared to 79 TL and 15 identity), and identity was mentioned the least. Across all subcomponents, *changed perception* then *experiential value* were mentioned the most (Table 5).

Among the TL subcomponents, *disorientation/awe* was the most likely to be mentioned. Identity-related responses were mentioned 15 times during interviews, usually related to science identity (across 5 instructors a total of 12 times) and not to nature identity (3 instructors, 3 times). Across all instructors, they mentioned some identity or transformative component an average of 40.7 times (range from 11–60). Not including Hazel's interview, to better compare numbers between these interviews and the observation results (Table 6), a total of 237 mentions of identity, TE, or TL were noted from interviews, with each instructor mentioning some aspect of these an average of 39.5 times.

Data generated from observations and document reviews of 6 of the instructors (Table 6) revealed that, across the ~250 minutes (about 8 hours) of observations and 4 documents, mention of TE was more likely to be mentioned or seen than TL (82 versus 24), just as with the interview data. Each of the subcomponents of TE and TL were identified across the sample, though *TL outcomes* were only mentioned once from one instructor observation or document (Gabe) versus 17 times during interviews. *TL critical dialogue* was only observed for Jack (online, asynchronous course instructor). I noted that several of Jack's online discussion board assignments require students to post substantive responses to other's video or written posts, and that some could lead to critical discourse.

Though missing from the observation sheet matrix, I did not hear *identity* components during my observations. The aspect that was most likely to be used, according to observations

and documents, was *experiential value*, followed by *changed perceptions* (flip-flopped from interview data), and then *disorientation/awe.* The mean number of observations or mentions of transformative teaching components (TL or TE) by the 6 instructors' assignments and 50-minute observations over ecology topics was 17.7 times, ranging from 13–28.

Combining the interview, observation, and document analysis data for the six pre-post instructors confirms the same trends previously noted: TE was coded most often followed by TL and then identity (Table 7). No instructor mentioned identity more than TL, and none mentioned TL more than TE. Viewing the data in this format reveals that no one instructor was always highest nor always lowest across all three constructs. Campus 1 had higher mean identity, TE, and TL than campuses 2 or 3, while campus 3 had the same or slightly more than campus 2. Despite those trends, Maggie (campus 3) had higher counts than Lucas (campus 1) for identity and TL and higher counts than Ava (campus 1) on TE.

Looking at the assigned transformative teaching level (IDT), as determined by z-scores, a general pattern emerged that instructors at campus 1 were classified as having higher overall levels of transformative teaching than those at campuses 2 or 3. Also, the online section (Jack) and sections that didn't have a separate ecology unit (Gabe) were classified as having the lowest levels of transformative teaching. These data were next used for additional quantitative analyses, the results of which are described later in this chapter.

Table 5

Counts of Identity and Transformative Goals and Teaching from Instructor Interviews

Instructor	Identity			Transformative Experience				Transformative Learning				
	Nature	*Science*	*Total*	*MU*	*CP*	*EV*	*Total*	*DA*	*CR*	*CD*	*O*	*Total*
Hazel	0	4	4	10	19	4	33	6	0	4	1	11
Ava	1	5	6	6	8	9	23	9	8	9	2	28
Lucas	0	1	1	11	23	9	43	9	2	2	3	16
Jack	0	1	1	4	11	4	19	0	0	2	0	2
Sam	0	0	0	3	13	10	26	1	0	0	4	5
Maggie	1	1	2	8	18	12	38	3	4	2	7	16
Gabe	1	0	1	2	5	2	9	1	0	0	0	1
By Category												
Total	3	12	15	43	97	50	191	29	14	19	17	79
Mean	0.4	1.7	2.1	6.2	13.9	7.1	27.3	4.1	2.0	2.7	2.4	11.3
Median	0	1.0	1.5	6.0	13.0	9.0	26.0	3.0	0	2.0	2.0	11.0

Note. MU = motivated use; CP = changed perceptions; EV = experiential value; DA = disorientation or awe; CR = critical reflection; CD = critical discourse; O = outcome (expanded perspective or behavior).

Table 6

Counts of Transformative Goals and Teaching from Instructor Teaching Observations and Document Review

Instructor	Modality	Transformative Experience				Transformative Learning					Total
		MU	*CP*	*EV*	*Total*	*DA*	*CR*	*CD*	*O*	*Total*	
Ava	f2f	0	4	9	13	4	1	0	0	5	18
Lucas	f2f	3	5	18	26	2	0	0	0	2	28
Jack	online, a	0	4	7	11	3	2	3	0	8	19
Sam	f2f	3	2	8	13	1	0	0	0	1	14
Maggie	f2f	1	2	6	9	2	3	0	0	5	14
Gabe	f2f	3	3	4	10	1	1	0	1	3	13
By Category											
Total		10	20	52	82	13	7	3	1	24	106
Mean		1.7	3.3	8.7	13.7	2.2	1.2	0.5	0.2	4.0	17.7
Median		2.0	3.5	7.5	12.0	2.0	1.0	0	0	4.0	16.0

Note. MU = motivated use; CP = changed perceptions; EV = experiential value; DA = disorientation or awe; CR = critical reflection; CD = critical discourse; O = outcome (expanded perspective or behavior); f2f = face to face; online-a = asynchronous format.

Table 7

Total Transformative Goals and Teaching by Subcategory for Instructors across Interviews, Documents, and Observations

Instructor	ID			TE			TL			IDT		
	Total	Z-Score	Level	Total	Z-Score	Level	Total	Z-Score	Level	Sum	Z-Score	Level
Ava	6	1.9	high	36	-0.2	med	33	1.6	high	75	0.7	high
Lucas	1	-0.4	med	69	1.7	high	18	0.2	med	88	1.3	high
Jack	1	-0.4	med	30	-0.6	low	10	-0.5	med	41	-0.7	low
Sam	0	-0.9	low	39	-0.6	med	6	-0.9	low	45	-0.5	med
Maggie	2	0.1	med	47	0.4	med	21	0.5	med	70	0.5	med
Gabe	1	-0.4	med	19	-1.2	low	4	-1.0	low	24	-1.4	low
By Category												
Total	11			240			92			343		
Mean	1.8			40.0			15.3			57.2		
Median	1.0			37.5			14.0			57.5		

Note. ID = identity; TE = transformative experience; TL = transformative learning; IDT = composite of ID, TE, and TL counts

Quantitative Results

Paired sample t-tests for Hazel's comparison group of students revealed no significant difference in scores over time on the TEQ or EIS instruments, but their scores on the TROPOS instrument were significantly higher for the second- than first-instance survey (t[59] = 2.36, p = .011), with a small effect size using Cohen's (1988) conventions (d = .305) (Table 8). That is, students self-reported significantly higher instances of transformative learning over ecology topics (M = 3.53, SE = .06) late in the semester compared to mid-semester directly after their coverage of ecology content (M = 3.42, SE = .05).

Table 8

Paired Sample t-Tests of Comparator Group by Time for Three Instruments

Instrument	Hazel Section				Other Sections			
	M	*SD*	*t(59)*	*Sig* [a]	*M*	*SD*	*t(198)*	*Sig* [b]
TEQ-post	2.69	.52			2.73	.48		
TEQ-pre	2.63	.41	1.48	.072	2.50	.43	8.40	<.001
TROPOS-post	3.53	.44			3.57	.46		
TROPOS-pre	3.42	.41	2.36	.011	3.45	.36	4.93	<.001
EIS-post	3.46	.49			3.51	.54		
EIS-pre	3.39	.53	1.47	.074	3.42	.57	3.73	<.001

Note. The sample size of Hazel's comparison section was 60 while the other sections had 199 pre-post-matched student survey participants. TEQ = Transformative Experience Questionnaire; TROPOS = TRansformative Outcomes and PrOcesses Scale; EIS = Ecological Identity Scale.
[a] Significance reported as one-tailed. [b] Significance reported as two-tailed.

Paired sample t-tests using data from the other 199 students (i.e., those in non-Hazel sections) who took pre-post surveys around ecology teaching, revealed significantly higher post-survey than pre-survey scores for all three instruments (Table 8). Students self-reported significantly higher TE (mean difference = 0.23, t[198] = 8.40, p < .001), TL (0.12, t[198] =

4.93, p < .001), and ecological identity (0.09, t[198] = 3.73, p < .001) on post-surveys versus pre-surveys. Effect sizes as measured by Cohen's d were medium (.60) for TE and small for TL (.35) and ecological identity (.26) using Cohen's (1988) conventions.

Repeated measures ANOVAs with instructor by time on all three instrument's pre-post scores were examined next. As Jack's section only had two respondents, they were excluded from these analyses due to insufficient sample size that could mask impacts of the instructor by time interaction. This left 196 respondents, from sections other than Hazel's, who had followed a true pre-post survey setup, after outliers and Jack's students were removed. Confirming the earlier paired t-tests, all three showed significant post > pre scores on the main effect of time with large (TEQ) or small (TROPOS and EIS) effect sizes (Table 9). There were no statistically significant interaction effects between instructor and time for TEQ (F[4, 191] = 1.32, p = .26) or EIS (F[4, 191] = 1.23, p = .298) scores, with small effect sizes. However, the equality of covariance matrices assumption indicates violation for the TEQ (Box's M = 26.63, p = .013), perhaps due to unequal and some small sample sizes by cell. Examining Pillai's Trace, instead of Wilks' Lambda, to interpret the multivariate results output the same results, so examination of univariate analyses is more trustworthy. It leads to the same outcomes. These results also indicated the importance of later analyses of TEQ by instructor teaching *level* to improve sample size by cell and prevent assumption violation.

For TROPOS scores by instructor, there was a significant instructor by time interaction (F[4, 191] = 2.58, p = .039) with a medium effect size. However, the equality of covariance matrices assumption was again violated for scores on this instrument (Box's M = 27.21, p = .011), as was the test of equality of error variances for TROPOS-post (Levene's statistics [trimmed mean] = 3.31, p = .012). This, again, indicated use of univariate analyses instead, and it

justified further analyses by instructor *level* to better understand the data.

Table 9

Two-Way Repeated Measures ANOVA Summary Table for Three Instruments by Instructor

Instrument	Source	SS	df	MS	F	Sig	Partial η^2
TEQ	Between subjects						
	Instructor	0.87	4	0.21	0.65	.630	.013
	Error	63.91	191	0.34			
	Within subjects						
	Time	2.54	1	2.54	34.39	<.001	.153
	Instructor x Time	0.39	4	0.10	1.32	.263	.027
	Error	14.08	191	0.07			
TROPOS	Between subjects						
	Instructor	4.54	4	1.14	4.37	.002	.084
	Error	49.70	191	0.26			
	Within subjects						
	Time	0.34	1	0.34	5.97	.016	.030
	Instructor x Time	0.59	4	0.15	2.58	.039	.051
	Error	10.91	191	0.06			
EIS	Between subjects						
	Instructor	2.52	4	0.63	1.10	.356	.023
	Error	109.07	191	0.57			
	Within subjects						
	Time	0.32	1	0.32	5.62	.019	.029
	Instructor x Time	0.28	4	0.07	1.23	.298	.025
	Error	10.87	191	0.06			

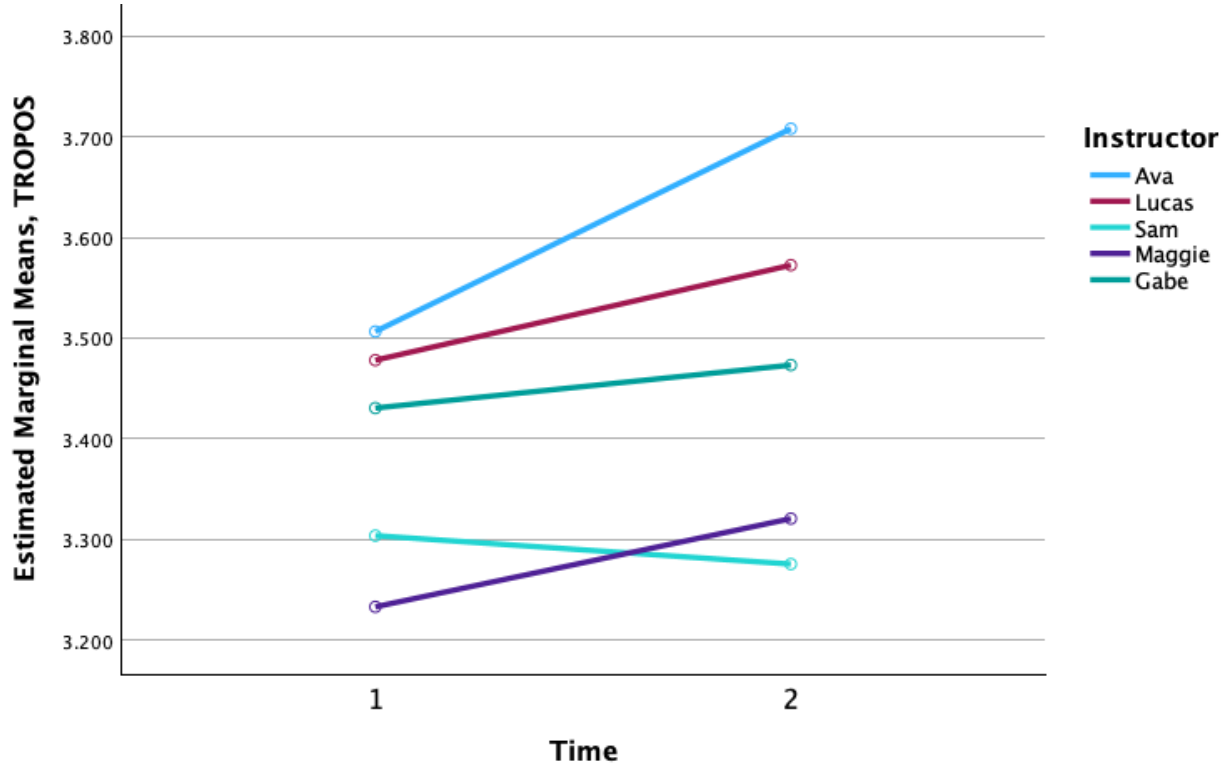
Note. n = 196 across 5 instructors; TEQ = Transformative Experience Questionnaire, test assumptions not met; TROPOS = TRansformative Outcomes and PrOcesses Scale, test assumptions not met; EIS = Ecological Identity Scale.

Post hoc analyses of the significant instructor by time interaction for TROPOS using pairwise comparisons based on estimated marginal means showed that there were not significant differences between instructor for TROPOS-pre, but for TROPOS-post scores, Ava's students had significantly higher scores (M = 3.71) than Sam's (M = 3.28, p = .023), Maggie's (M = 3.32,

p = .033), and Gabe's (M = 3.47, p = .026) students. Pairwise by instructor, only Ava's students had significantly higher TROPOS-post than TROPOS-pre (Pillai's trace = .14, F[1, 191] = 32.25, p < .001, Partial η^2 = .14). A profile plot was generated to visualize this change of estimated marginal means of TROPOS by instructor across the two time points (Figure 7).

Figure 7

Profile Plot of Change in TROPOS Scores over Time by Instructor



Note. TROPOS = TRansformative Outcomes and PrOcesses Scale.

Next, repeated measures ANOVAs with campus by time on all three instrument's pre-post scores were examined next using the same 196 respondents. Findings by campus were similar as the analyses by instructor: No statistically significant interaction effect was found between campus and time for TEQ (F[1, 194] = 0.45, p = .506) or EIS (F[1, 194] = 0.32, p = .575) scores, with small effect sizes and statistical test assumptions all met. For TROPOS

scores, there was a significant campus by time interaction (F[1, 194] = 7.36, p = .007) with a small effect size (Table 10); however, for TROPOS-post there was violation of the test of equality of error variances (Levene's statistic [trimmed mean] = 4.41, p = .037). Since outliers had already been examined, this again indicated use of univariate results and qualitative data by campus to understand trends.

Table 10

Two-Way Repeated Measures ANOVA Summary Table for Three Instruments by Campus

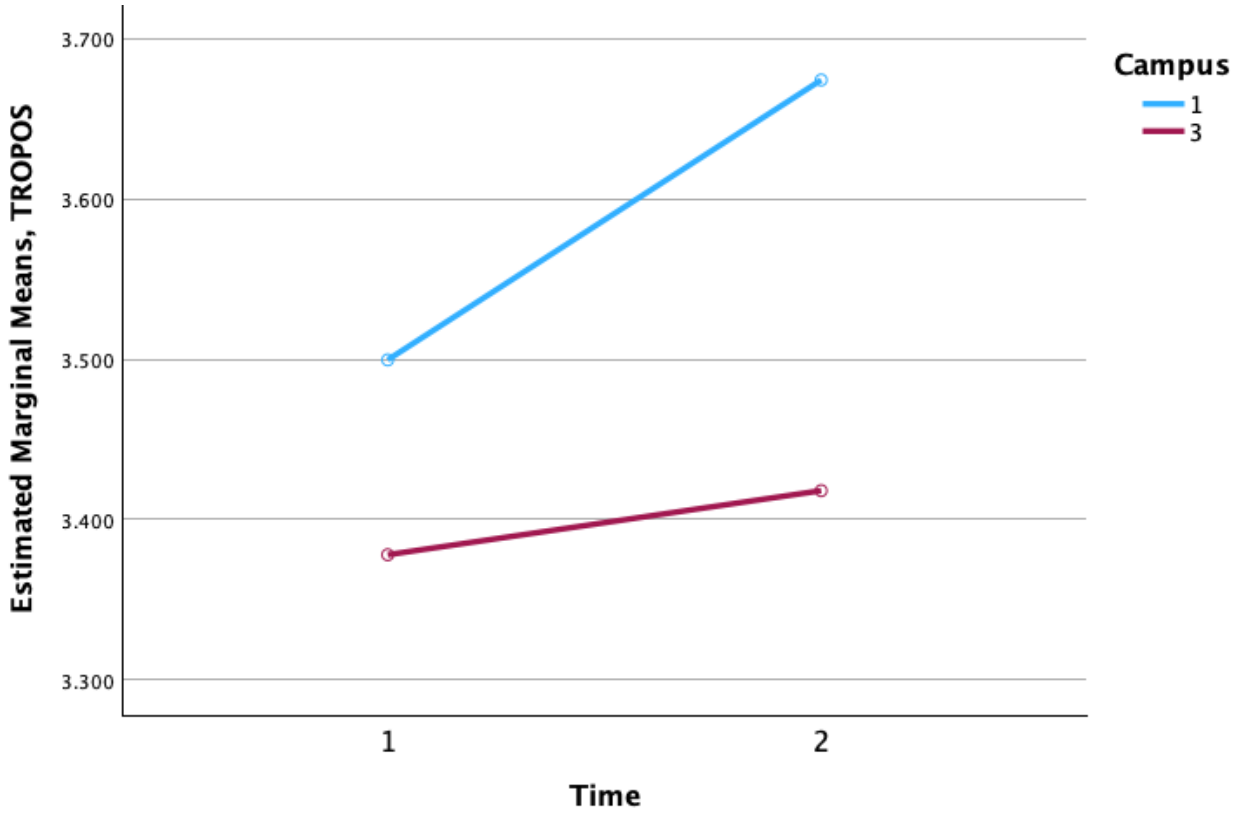
Instrument	Source	SS	df	MS	F	Sig	Partial η^2
TEQ	Between subjects						
	Campus	0.52	1	0.52	1.58	.211	.01
	Error	64.25	194	0.33			
	Within subjects						
	Time	5.19	1	5.19	69.72	<.001	.26
	Campus x Time	0.03	1	0.03	0.45	.506	.002
	Error	14.43	194	0.07			
TROPOS	Between subjects						
	Campus	3.31	1	3.31	12.60	<.001	.06
	Error	50.94	194	0.26			
	Within subjects						
	Time	1.07	1	1.07	18.69	<.001	.09
	Campus x Time	0.42	1	0.42	7.36	.007	.04
	Error	11.08	194	0.06			
EIS	Between subjects						
	Campus	0.19	1	0.19	0.34	.564	.002
	Error	111.40	194	0.57			
	Within subjects						
	Time	0.75	1	0.75	13.15	<.001	.06
	Campus x Time	0.02	1	0.02	0.32	.575	.002
	Error	11.13	194	0.06			

Note. n = 196 across 2 campuses, after removal of additional outlier and Jack's section with only 2 student participants; TEQ = Transformative Experience Questionnaire; TROPOS = TRansformative Outcomes and PrOcesses Scale, test assumption not met; EIS = Ecological Identity Scale.

Post hoc analyses of the significant campus by time interaction for TROPOS using pairwise comparisons based on estimated marginal means showed that campus 1 had significantly higher TROPOS-pre (M = 3.50, p = .020) and TROPOS-post scores (M = 3.67, p < .001) than campus 3 (M = 3.38 and 3.42 respectively). Pairwise by campus, only campus 1 students had significantly higher TROPOS-post than TROPOS-pre scores (Pillai's trace = .14, F[1, 194] = 32.33, p < .001, Partial η^2 = .14). A profile plot was generated to visualize this change of estimated marginal means by campus across the two time points (Figure 8).

Figure 8

Profile Plot of Change in TROPOS Scores over Time by Campus



Note. TROPOS = TRansformative Outcomes and PrOcesses Scale.

A simple linear regression was conducted to determine if changes in TEQ scores predicted changes in TROPOS scores for the sample of 198 pre-post matched respondents.

Results were significant ($F[1, 196] = 46.33$, $p < .001$) with a standardized beta of .44 indicating a medium relationship between those variables (Cohen, 1988). The R^2 was .191 indicating that TEQdiff explained approximately 19.1% of the variation in TROPOSdiff. No evidence of collinearity was found (tolerance = 1.00, VIF = 1.00). In a buildup strategy, I next analyzed if TROPOSdiff predicted EISdiff for that same dataset and found significance ($F[1,196] = 40.89$, $p < .001$) with a standardized beta of .42 (medium relationship). TROPOSdiff explained approximately 17.3% of the variation in EISdiff with no evidence of collinearity (tolerance = 1.00, VIF = 1.00).

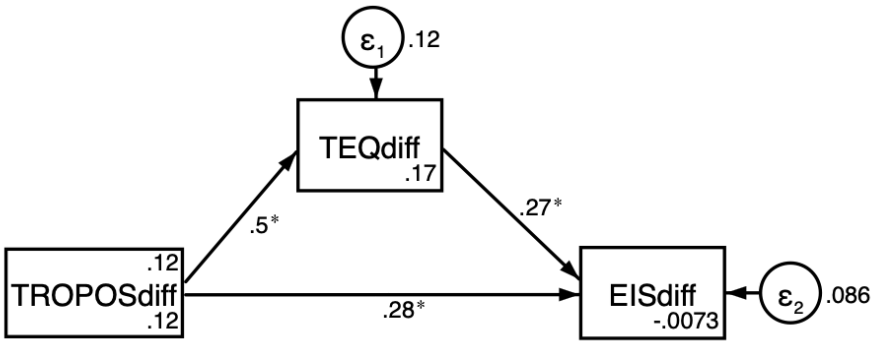
A multiple linear regression testing the predictive power of both TEQdiff and TROPOSdiff on EISdiff was also significant ($F[2, 195] = 32.76$, $p < .001$) with an R^2 of .251 indicating that TEQdiff and TROPOSdiff together explained approximately 25.1% of the variation in EISdiff. Standardized beta coefficients revealed that TEQdiff ($\beta = .31$) had the stronger predictive relationship to EISdiff than TROPOSdiff ($\beta = .28$), where both had a medium relationship (Cohen, 1988). There was no evidence of multicollinearity (tolerance = .81, VIF = 1.24).

To further explore the relationship of TE and TL on each other and on ecological identity, given those significant regression results, I modeled the relationships with path analysis. I conducted a structural equation model in STATA to test the mediation effect of TE change (TEQdiff) on the relationship between changes in TL (TROPOSdiff) and shifts in ecological identity (EISdiff) (Figure 9). Parameter estimates revealed significant positive associations along all paths at $p < .001$. Importantly, the indirect effect of TROPOSdiff on EISdiff via TEQdiff was significant (unstandardized $b = .14$, $p < .001$), indicating that the relation between changes in TL and ecological identity is partially mediated by change in TE. This overall model demonstrated

excellent fit to the data, with fit indices indicating a strong match between the hypothesized model and the observed data: Comparative Fit Index (CFI) = 1.00, Tucker–Lewis Index (TLI) = 1.00, and Standardized Root Mean Square Residual (SRMR) < .001. Equation-level goodness of fit shows this model explained 25.4% of the variation in EISdiff.

Figure 9

Structural Equation Model with Unstandardized Coefficients of TEQdiff Mediating the Relationship between TROPOSdiff and EISdiff



Note. n = 198 and unstandardized coefficients shown; TROPOSdiff = TROPOS-post minus TROPOS-pre scores; TEQdiff = TEQ-post minus TEQ-pre scores; and EISdiff = EIS-post minus EIS-pre scores.

* $p < .001$

Second Round Quantitative Results

Assigning each of the six pre-post instructors a level of high, medium, or low for their use or mention of identity, TE, TL, and the composite score of those three (Table 7) allowed for further quantitative analyses. This grouping helped improve sample size by cell, prevent violation of assumptions, and further answer my specific research question about the relationship of transformative teaching to student transformative shifts. Those level variables were added to

the quantitative survey dataset to allow two-way repeated measures ANOVAs with time as the within and instructor level as the between factor to look for differences and interactions across each survey instrument.

Table 11

Two-Way Repeated Measures ANOVA Summary Table for the TROPOS and EIS Instruments by Instructor TL Level

Instrument	Source	SS	df	MS	F	Sig	Partial η2
TROPOS	Between subjects						
	TL Level	3.02	2	1.51	5.70	.004	.06
	Error	51.65	195	0.27			
	Within subjects						
	Time	1.09	1	1.09	19.22	<.001	.09
	TL Level x Time	0.56	2	0.28	4.96	.008	.05
	Error	11.05	195	0.06			
EIS	Between subjects						
	TL Level	1.28	2	0.64	1.13	.325	.01
	Error	110.76	195	0.57			
	Within subjects						
	Time	0.84	1	0.84	14.54	<.001	.07
	TL Level x Time	0.07	2	0.04	0.61	.546	.01
	Error	11.29	195	0.06			

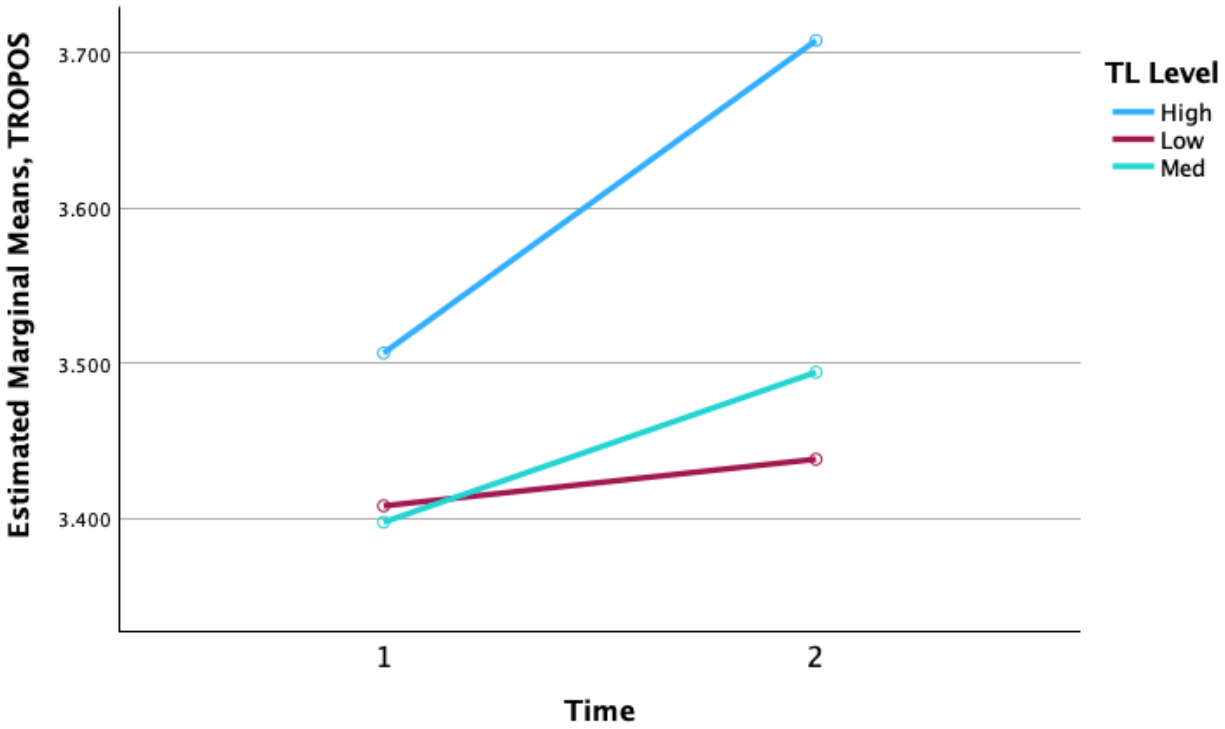
Note. n = 198 across 6 instructors; TROPOS = TRansformative Outcomes and PrOcesses Scale; EIS = Ecological Identity Scale; TL Level = assignment of high, medium, or low based on observation and interviews of instructor use of transformative learning.

In the first analysis, instructor TE levels were used to look for impacts over time on the student TEQ scores. No statistically significant interaction effect was found between instructor TE teaching level and time for the TEQ ($F[2, 195] = 1.81$, $p = .166$), with small effect size (partial $\eta^2 = .02$). Next, instructor TL teaching levels were used as the between factor to look for changes in TROPOS and EIS scores over time. There was no significant interaction of TL

teaching level by time for the EIS (F[2, 195] = 0.61, p = .546) with a small effect size, but the interaction of TL teaching level by time for the TROPOS was significant (F[2, 195] = 4.96, p = .008) with a medium effect size (Table 11). Equality of covariance matrices and the tests of equality of error variances assumptions were met for these analyses.

Figure 10

Profile Plot of Change in TROPOS Scores over Time by Instructor TL Level



Note. TL Level = assignment of high, medium, or low based on observation and interviews of instructor use of transformative learning; TROPOS = TRansformative Outcomes and PrOcesses Scale.

Post hoc analyses showed that for TROPOS-post (time 2), students in TL-high instructor sections had significantly higher scores (M = 3.71) than those in TL-med (M = 3.50, p = .026) and TL-low (M = 3.44, p < .001) sections. Pairwise comparisons by level showed that for students in TL-high sections, their TROPOS-post scores (M = 3.71) were significantly higher

than their TROPOS-pre scores (M = 3.51, F[1, 195] = 32.51, p < .001, partial η^2 = .14) with large effect size. This was not the case for TL-med (M = 3.50, F[1, 195] = 3.70, p = .056, η^2 = .02) or TL-low sections (M = 3.44, F[1, 195] = 0.49, p = .483, η^2 = .003) with small effect sizes. A profile plot was generated to visualize this change of estimated marginal means of TROPOS scores by instructor TL teaching level from pre- to post-test (Figure 10).

Table 12

Two-Way Repeated Measures ANOVA Summary Table for Three Instruments by Instructor Transformative Teaching Level (IDT)

Instrument	Source	SS	df	MS	F	Sig	Partial η^2
TEQ	Between subjects						
	IDT Level	0.75	2	0.37	1.12	.328	.01
	Error	64.83	195	0.33			
	Within subjects						
	Time	2.77	1	2.77	35.97	<.001	.16
	IDT Level x Time	0.18	2	0.09	1.17	.313	.01
	Error	15.01	195	0.08			
TROPOS	Between subjects						
	IDT Level	4.31	2	2.15	8.33	<.001	.08
	Error	50.36	195	0.26			
	Within subjects						
	Time	0.48	1	0.48	8.37	.004	.04
	IDT Level x Time	0.40	2	0.20	3.52	.032	.04
	Error	11.21	195	0.06			
EIS	Between subjects						
	IDT Level	0.13	2	0.06	0.11	.897	.001
	Error	111.92	195	0.57			
	Within subjects						
	Time	0.34	1	0.34	5.88	.016	.03
	IDT Level x Time	0.07	2	0.03	0.57	.567	.01

Note. n = 198. IDT Level = transformative teaching level as determined from composite of identity, transformative experience, and transformative learning qualitative data; TEQ =

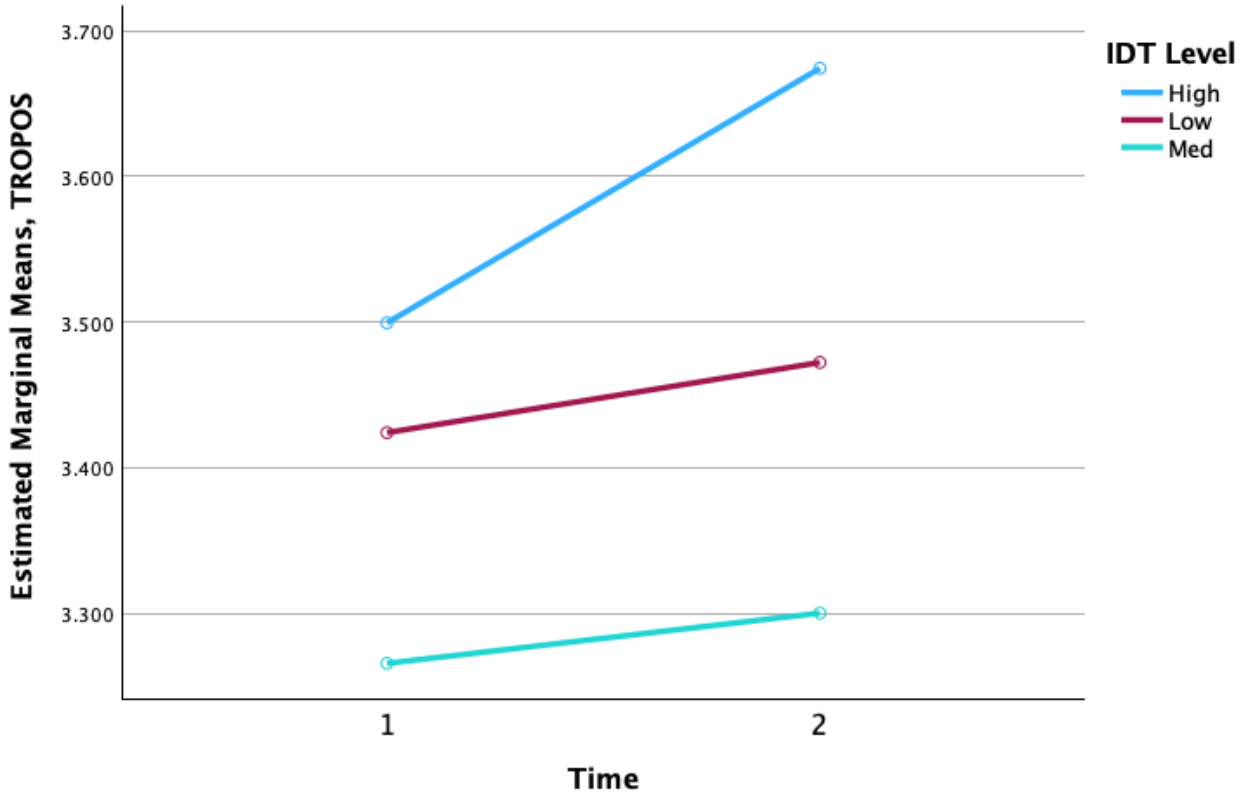
Transformative Experience Questionnaire; TROPOS = TRansformative Outcomes and PrOcesses Scale; EIS = Ecological Identity Scale.

The final analyses used overall transformative teaching level as the between factor and time as the within factor, looking across all three instruments. No statistically significant interaction effect was found between overall instructor transformative teaching level and time for the TEQ ($F[2, 195] = 1.17$, $p = .313$, $\eta^2 = .01$) or for the EIS ($F[2, 195] = 0.57$, $p = .567$, $\eta^2 = .01$) scores, with small effect sizes. For TROPOS scores though, there was a significant transformative teaching level by time interaction ($F[2, 195] = 3.52$, $p = .032$) with a small effect size ($\eta^2 = .04$) (Table 12). Equality of covariance matrices and the tests of equality of error variances assumptions were met for all three instruments.

Post hoc analyses of pairwise comparisons by time showed that for TROPOS-pre scores, students in sections with high transformative teaching had significantly higher scores ($M = 3.50$) than those in medium sections ($M = 3.27$, $p = .010$), and at TROPOS-post, students in high transformative teaching had significantly higher scores ($M = 3.67$) than those in medium ($M = 3.30$, $p < .001$) and those in low ($M = 3.47$, $p = .017$) sections. Pairwise comparisons by level showed that only for students in the high transformative teaching sections was TROPOS-post ($M = 3.67$) significantly higher than TROPOS-pre ($M = 3.50$, $F[1, 195] = 32.13$, $p < .001$, $\eta^2 = .14$) with large effect size. A profile plot was generated to visualize this change of estimated marginal means in TROPOS scores by instructor transformative teaching level from pre- to post-test (Figure 11).

Figure 11

Profile Plot of Change in TROPOS Scores over Time by Instructor Transformative Teaching Level (IDT)



Note. TROPOS = TRansformative Outcomes and PrOcesses Scale; IDT Level = transformative teaching level as determined from composite of identity, transformative experience, and transformative learning qualitative data.

Chapter 5: Discussion

Research Summary

My research used mixed methods in a naturalistic setting of nonmajor introductory biology courses to answer the questions: 1) What is the nature of transformative teaching in the ecology unit of a sample of nonmajor introductory biology sections? 2) To what extent does instruction that includes transformative teaching strategies predict students' transformative experience, transformative learning, and ecological identity shifts? And 3) To what extent does transformative experience mediate changes in students' transformative learning and ecological identities?

I expected campus 3 to have more transformative learning (TL) teaching methods and TL student shifts, since that was the only campus that mentioned transformative learning in their mission, vision, or values (Ehrmann, 2021, Chapter 8; King & Wimmer, 2020). I also hypothesized that students in course sections in which instructors used more transformative experience (TE) strategies would have significantly greater shifts in TE; those sections with more TL strategies would have students with greater shifts in both TL and ecological identity; and sections with overall higher transformative teaching would have students with significantly greater shifts across all three instruments (Garner et al., 2016; Heddy & Pugh, 2015; Kokkos, 2017). Finally, I hypothesized that TL and ecological identity shifts would be significantly and positively correlated (Illeris, 2014; 2017), and that TE would mediate the predictive relationship between TL shifts and ecological identity shifts.

Qualitative results indicated that teaching goals and methods across the seven instructors included identity, TE, and TL, with variation by instructor. All subcomponents of these constructs were also observed directly or noted from instructor interview responses or document

analysis. Campus 1 displayed higher mean use of transformative teaching than campuses 2 or 3. Quantitative analyses showed that student scores on all three instruments significantly increased pre-post in nine introductory biology sections (n = 199), though interaction effects of instructor by time and campus by time were only significant on the TROPOS survey, not the TEQ or EIS instruments. Some violations of equality of covariance matrices (TEQ and TROPOS) and the test of equality of error variances assumptions (TROPOS-post) were violated, indicating caution in interpretation and that further analyses were needed. Pairwise analyses of the instructor by time interaction showed that for TROPOS-post, Ava's students scored significantly higher than Sam, Maggie, & Gabe's students; and only students in Ava's section had TROPOS-post > TROPOS-pre at a significant level. Post hoc analyses by campus revealed that on TROPOS-pre and TROPOS-post, campus 1 > campus 3 and that for campus 1, TROPOS-post > TROPOS-pre.

Quantitized data from the counts of my qualitative data were used to assign levels of transformative teaching, then combined that with quantitative survey results to run two-way, repeated measures ANOVAs. Instructor TE-level did not appear to predict student TEQ scores, instructor TL-level did not predict student EIS scores, and overall instructor transformative teaching level (IDT-level) did not predict student TEQ or EIS scores. However, instructors' TL-level by time interaction and their IDT-level by time interaction were significant predictors of students' TROPOS score shifts.

Path analysis was used to investigate if the change in student TEQ scores acts as mediator in the relationship between TROPOS difference scores and EIS difference scores. This model was consistent with the data, indicated that TE shifts may mediate the impact of TL changes on student ecological identity changes.

The findings are discussed below, including their theoretical and practical implications

for education psychology (TE), adult education (TL), and sustainability education (ecological identity). Limitations and future research into this area of inquiry are also proposed.

Question 1: Transformative Teaching in Ecology

In select cases in naturalistic settings across seven instructors, three campuses, and two states, I noted the presence of instructor goals and methods that could be classified as subcomponents of identity, TE, and TL. These appeared during my observations of course lectures and in-class activities, examination of out-of-class assignment documents, instructor mention of these activities, or instructor direct response to questions about transformative teaching components during interviews.

There were more mentions of TE than TL, and more mentions of TL than identity. This may be because TE is a composite of several areas of research in educational psychology: Interest, emotion, motivation, transfer, conceptual understanding, and others (Pugh, 2011, 2020). As such, it is more likely that instructors have received some sort of faculty development (e.g., training at their campus, at professional conferences, through reading articles or chapters on best practices in education) related to one or more areas of TE that they may have integrated into their teaching. The TL and identity constructs may be more specialized to adult education and sociology, respectively, making it less likely that a biology instructor would have encountered them. Nonetheless, science identity is a key area of inquiry within STEM education (Carlone & Johnson, 2007; Hazari et al., 2013) and specific training in TL does exist for higher education faculty (King & Wimmer, 2020). This may help explain why all subcomponents of the constructs were present in qualitative data.

With this sample of instructors, the hypothesis that campus 3 would have higher instances of TL in ecology than the other two campuses was shown to be incorrect. Because these

qualitative data used a small sample size (N = 7), these results may not be generalized to other instructors at those campuses. Though campus 3 includes TL in their mission, vision, and faculty development offerings, the instructors that participated in this study may not have completed training in TL or may have completed training but chose not to implement it in their ecology unit of their course. Alternatively, instructors at the other campuses may have been trained in TL methodology even without their campus' focus on TL, and/or they may have adopted parts of their course design from other instructors who used TL.

Within TE, the subcomponents I noted most often from instructors were changed perception (from interviews) and experiential value (from observations/documents). Most instructors in this study emphasized that they wanted their students to find use for, or relevance of, ecology concepts in their everyday lives. That is, beyond just being motivated to use the concepts, instructors desired their nonmajors to value the ecology principles being taught and have a changed perception of the importance of ecology in helping them make decisions and interact with others. This current study did not focus on course alignment between instructor goals, stated learning outcomes, assessments, and learning activities to know if instructor desires for student transformation matched with activities to promote those. Quantitative evidence, covered next, suggests that students did achieve transformative results. Qualitative data imply that faculty could benefit from training and modeling of the integration of all subcomponents of TE and TL with an identity focus, to help them reach some of their desired student outcomes.

Question 2: Transformative Student Shifts

To answer my second main research question, three waves of analysis were employed. First, quantitative data were analyzed to see if there were differences in students' pre-post scores on any of the instruments, including comparisons to a group of students in which no change was

expected. Next, I used repeated measures ANOVAs to examine if there were instructor by time and campus by time interactions on any of the three scales. Finally, using those quantitative data and quantitized qualitative data, I employed repeated measures ANOVAs again to understand if transformative teaching levels predicted student score shifts across the three constructs.

Paired sample t-tests showed that the comparison group of students (Hazel's, n = 60), who took both rounds of surveys after their ecology unit, had no significant increases on the TEQ or EIS surveys, but did have significant increases in TROPOS scores (one-tailed p = .011). I would have expected their scores to not significantly change, since they would have already had their ecology content delivered and would have completed their reflections on that content prior to the first survey.

One potential explanation for the increase is social desirability (Krumpal, 2013) - students thought the researcher expected a higher score at the second survey, so they answered with higher-number responses. However, there was not an increase in the TEQ or EIS surveys, taken concomitantly with the TROPOS, so that does not seem like the most likely explanation for the TROPOS score changes. Another explanation could be that students continued to reflect and take action on transformative thoughts, even after the unit's conclusion, and continued a growth trajectory in that construct but not the others (Alhadeff-Jones, 2019). The instructor could have even facilitated this by continuing to connect ecology concepts to later content (e.g., evolution, physiology) enhancing opportunities for critical reflection and transformative learning growth. A final explanation is that by taking the TROPOS to assess TL, it enhanced students' further TL shifts, since they were now made conscious of critical reflection over ecology and potential shifts in their ecological perspectives (Acheson & Dirkx, 2021). Having a third timepoint for survey data collection, both for this comparison group and the others, would have

provided additional information to help clarify this unexpected result.

For students in the other six instructors' sections (n = 199), paired-sample t-tests showed higher post- than pre-survey scores on all three instruments at $p < .001$. These results were confirmed on the later repeated measures ANOVAs through which the simple main effects for time were statistically significant. The effects of time during the between-factor instructor analyses were significant for the TEQ ($p < .001$), TROPOS ($p = .016$), and EIS ($p = .019$) scores; and then again with the between-factor of campus, time was significant at $p < .001$ on all three scales.

These further data, the larger sample for this group versus the comparison group, and seeing significant results across all three instruments indicate that some part of the ecological content may be impacting student shifts. In summarizing the research on TE in K–12, Pugh et al. (2019) indicated that TE did not appear to be happening in that context without teacher intervention (e.g., TTES). So, in higher education, some aspects of TE could be employed by instructors even without training in TE-specific pedagogies; and/or some characteristics of the educational environments are leading to student TE. Similarly, TL and identity shifts can happen without integration of specific methods (Burke & Stets, 2023; Illeris, 2014; Walter, 2013; Watkins et al., 2018), though learning environments can be designed to increase the incidence of TL growth (Colomer et al., 2020; Cranton, 2016) and ecological identity shifts (McGuire, 2015; Scott, 2023).

To further understand the impacts of instructor transformative teaching on student survey results, interaction effects from the ANOVAs and additional repeated measures ANOVAs by instructor transformative levels are interpreted. My data showed significant interaction effects of both instructor by time and campus by time for TROPOS scores, but not for the TEQ or EIS

scores. That is, students' changes in TROPOS scores were dependent on which instructor they had or which campus they attended. Since instructors are embedded within campuses, and my qualitative data focused on the individual instructors, those data were used next to help explain the interaction effects.

Integrating the counts of instructor transformative teaching with the student scores allowed further analyses. My hypothesis that higher instructor levels of TE would predict student TEQ scores was not supported using repeated measures ANOVAs. That is, student TEQ scores were significantly higher at the end of the semester, regardless of their instructor's TE-level. My hypothesis that instructor TL-level would predict both student TROPOS and EIS scores was partially supported: Instructor TL-level predicted TROPOS but not EIS scores. Univariate analyses of EIS revealed that for students in TL-high ($p = .023$) and TL-med ($p = .007$) instructor sections, their EIS-post scores were significantly higher than their EIS-pre scores. So, there is evidence that higher levels of instructor TL teaching are tied to greater shifts in student ecological identity, even absent a significant interaction effect. Post hoc analyses for TROPOS showed that at TROPOS-pre, student scores were not significantly different by instructor TL-level, but by TROPOS-post, students in TL-high sections had significantly higher scores than those in TL-med or TL-low sections. Also, only in the TL-high sections were students' TROPOS-post scores significantly higher than their TROPOS-pre scores. Together, these results indicate that instructor goals and teaching that incorporate more transformative learning help predict students' TL and ecological identity shifts.

The final set of repeated measures ANOVAs tested the overall instructor transformative teaching level (IDT level) by time on all three instruments. There were no significant interaction effects on the TEQ or EIS scores, and univariate analyses showed similar patterns as with prior

analyses. TEQ scores seemed to increase regardless of instructor level (IDT-high and IDT-low students had significant increases at $p < .001$), but on the EIS, scores significantly increased pre-post ($p < .001$) only for the IDT-high groups of students.

The interaction effect of IDT level by time was significant for the TROPOS instrument, with post hoc analyses showing that for the IDT-high students, they started out significantly higher on TROPOS than the IDT-med students. By TROPOS-post, though, the IDT-high students scored significantly higher than their TROPOS-pre scores and than the TROPOS-post scores of both the IDT-med and IDT-low students. Again, these results point to the important impact of instructors' goals and inclusion of transformative teaching (identity-based, TE, and TL) on non-biology major, university students' transformative learning, and potentially their ecological identity. However, these students indicate having transformative experiences even without instructors explicitly being trained on and including more TE strategies in their teaching.

Question 3: Transformative Experience Mediation

To answer my third research question, I first used regression analyses on instrument difference scores to find that TEQdiff was a statistically significant and positive predictor of TROPOSdiff, accounting for 19.1% of the variation in students' change in TL scores. Also, TROPOSdiff was a significant and positive predictor of EISdiff, accounting for 17.3% of the variation in student ecological identity difference scores. A multiple linear regression showed that both TEQdiff and TROPOSdiff were positive and significant predictors of EISdiff, accounting for 25.1% of the variation in student ecological identity scores. That is, students' TE shifts predicted their TL and ecological identity shifts; further, their TL shifts predicted their ecological identity shifts.

The observed mediation effect of TEQdiff in the structural equation model supports the

theoretical perspective that increases in TE serve as a key mechanism linking changes in TL to shifts in ecological identity in this population of nonmajor introductory biology students covering ecology content. Beyond student TL shifts directly impacting their ecological identity shifts, the students noticing ecology concepts in their everyday lives, changing how they see that experience, and now valuing the ecological concept for its usefulness (i.e., TE; Pugh, 2020) mediates the centralizing of their ecological identities amongst their multiple identities.

Given that TE is present in both instructional design/teaching and in student outcomes in the ecology units of nonmajors biology in these select cases, and that TE mediates the impacts of TL on ecological identities, there are course design implications. The explicit use of TE teaching methods, for example through the integration of TTES for the ecology unit that includes multiple rounds of student reflections (Tarabochia & Heddy, 2019), could enhance its impact on promoting students' ecological identity shifts. This is especially important in conjunction with TL teaching methods.

Limitations

There are limitations to this study which, in knowing, help with interpretation and application of these findings. Participants were not sampled randomly, so even with satisfactory sample size, they may not have provided the same characteristics of the population compared to a fully randomized study. Also, the limited number of instructors and campuses from which data were collected prevents generalizing findings to the larger population of nonmajor biology instructors and students. Finally, when analyzing data at the student level, clustered by instructor, sample sizes were uneven and some were small, resulting in some instances of nonnormal distributions and violation of test assumptions. This may have led to an increased probability of error in results, so multiple ways to analyze data and tests more robust to violation of

assumptions were used.

The use of already-established groupings of research participants (i.e., students already enrolled in existing course sections at universities) prevented random assignment of subjects to the comparison section (Hazel's) and the other sections. This introduced the potential for clustered data by section and a potential source of bias in results, though this is a common occurrence in educational research. Probabilistic, simple random sampling of nonmajor introductory biology courses within and across more states could have produced results for generalizing across the full population of undergraduate nonmajors in the U.S. This setup would have introduced other sources of error, though, due to differences in campus culture, ecology content, and other unknown factors.

The inability to control student sociohistorical factors, differences in physical learning environments, and variation in campus cultures could have influenced quantitative student survey results. A sufficient sample size of students was sought to still uncover trends in the data beyond any source of error from these other factors. Instructor personality, teaching style, years of experience, and demographics could have influenced student survey responses. Not all of these characteristics were considered when gathering observation, interview, and document data from instructors to better control for them when correlating instructor teaching with student survey score shifts.

In a more controlled study environment (e.g., clinic, off-site environment), one instructor teaching multiple sections with a large sample size may have helped control some validity threats from instructor differences. This may have helped isolate the differences in student scores as being from differences in students or teaching methods. However, having different instructors, sections, and locations allowed the variability needed to correlate the qualitative transformative

teaching data with student survey differences – a purposeful design component of this study. As can often happen in educational research, logistics did not allow for such a controlled experimental design, so pre-post student response scores were analyzed by instructor, and a sufficient sample size was sought to help validate results.

The selection and recruitment of instructors could have also introduced bias in qualitative results, since maximum variation and opportunistic sampling was used (Creswell & Poth, 2018). As such, those instructors who agreed to participate could be unrepresentative of the average nonmajors introductory biology instructor in the United States at four-year universities. Further, during my observations of instructors, they were aware of my presence, which could have influenced their style or content of teaching.

Finally, while the desired sample size was reached overall and was expected to be sufficient to minimize attrition effects and departure from normality, some nonnormality was present when analyzing quantitative data by instructor on one or more surveys. The low participation at campus 2, both by having only one instructor and only two students completing both pre- and post-surveys, prevented comparisons across all three campuses and all six pre-post instructors.

The goal of this dissertation research was not to generalize to the larger population of undergraduate nonmajors or introductory biology instructors nationwide, but instead to gather baseline data on the presence of transformative teaching and student transformative shifts in select cases. Results provide initial findings about the relationship of three constructs never empirically examined together prior to this study. This study serves to guide future research that could seek more generalizable outcomes through wider observations and/or a quasi-experimental or experimental design, as described in the next section.

Future Research

The results of this study indicate the need for ongoing exploration of the relationships between transformative experience, transformative learning, and ecological identity in the realms of biology and environmental education. Future research could include repeating the data collection at other campuses with additional instructors to validate results, which would increase the sample size overall and for each group of students by instructor. Alterations to the current design could include adding a third timepoint and collecting observation, interviews, and documents from all participating instructors for analysis. These larger sample sizes would allow more in-depth analyses using alternate structural equation models, multilevel modeling, and factor analysis to better understand the relationship between the constructs. This same area of inquiry could also be extended to other contexts within and outside higher education, to better understand the three constructs and their interactions. Other future directions could include an instrument development study, resulting in a new tool to measure student TL shifts as defined by identity shifts, and the implementation of a quasi-experimental intervention study to better understand the impacts of different teaching methods on student transformative shifts.

Repeating the study at additional campuses with more instructors and students would provide a larger sample size to help validate the findings of this dissertation research. If the trends I found at three campuses across seven instructors hold true across additional campuses and instructors, the combined findings would be more generalizable and applicable to the larger population of nonmajor introductory biology students. This larger sample would be more likely to display normal distribution, as a whole and by instructor, leading to more trustworthy results.

The study could be modified slightly by collecting data from students across three timepoints, ideally once at the start of the semester, once after the ecology unit, and once several

weeks after the end of the semester. These data could help researchers better understand the trajectory of changes and the permanence of shifts across the three constructs. This may be particularly important for measuring TL, as one aspect of recognizing that TL has happened is relative stability over time and across new contexts (Hoggan, 2016b; Kyle & Walvoord, 2024). In addition, ensuring interview, observation, and assignment documents are collected for each participating instructor would help produce even more robust qualitative data through triangulation (Creswell & Poth, 2018). Gathering information about instructors' professional development and teaching history, as well as the presence or absence of a linked lab section where they are receiving further ecology content, would also provide valuable information for interpreting qualitative data and for inclusion in mixed methods analyses.

Larger sample sizes at the level of each instructor, and overall, would also allow for additional analyses of the data. Multi-level modeling could further explore if the differences in scores are clustered by instructor or campus (with students at level one, instructor and campus at level two). The sample size needed for this sort of analysis was determined using PowerUp! (Dong & Maynard, 2013). An effect size of .505 and intraclass correlation coefficient (ICC) of .04 was set, based on pilot research using the EIS (Walvoord & Heddy, 2025); an average cluster size (number of students per instructor) of 50, .01 variance in students explained by a covariate (demographic information), and .13 variance in scores by instructor was also used. The software indicated that for a two-level model by instructor, at least 10 instructors or campuses were suggested for a power of .8 with those parameters, equaling a total sample size of 500 students.

If an even larger sample across at least seven states was recruited, an analysis by state at level three of the cluster analysis could be performed as well. These larger sample sizes could

also allow further exploration of other paths in structural equation modeling. These could include moderated-mediation or inclusion of different subcomponents of each scale as indicators, to better understand if and how TE helps mediate and/or moderate the impacts of student TL on ecological identity shifts.

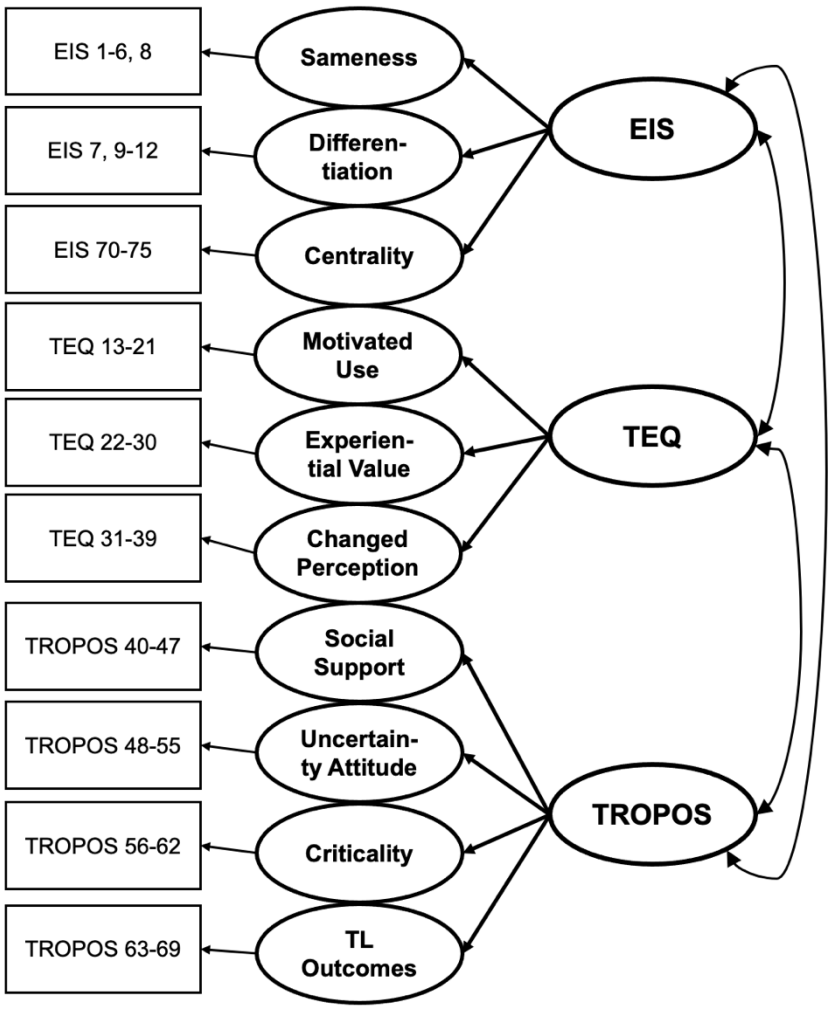
For a study of that scale, it would then be possible to further explore the constructs by examining the subscales of each of their respective instruments (Appendix E). Based on the development of those instruments, theoretical underpinnings, and prior research, I would hypothesize positive correlations between: TROPOS Social Support and EIS Sameness due to their emphasis on social components and the anticipated classroom environment where students are likely to feel a sense of camaraderie and campus cultural shared identity; and EIS Centrality and all three TEQ subscales, because students, at least in a double-treatment setup where both TTES and TL methods are used, should have more opportunities to validate their ecological identities, increasing that identity's prominence, salience, or commitment (and therefore, its centrality; Burke & Stets, 2023). Further, a relationship between TEQ Changed Perceptions and TROPOS Outcomes (i.e., expanded perceptions or behaviors) may give evidence for or against Heddy and Pugh's (2015) hypothesis that multiple TEs could lead to TL.

A confirmatory factor analysis (CFA) could be performed using the 10 subcomponents of the compiled instrument (Appendix E). A first order CFA could be performed to see how much variability in scores for each of the 75 questions would be accounted for by their respective latent variables (e.g., the seven EIS Sameness questions' variabilities accounted for by that first order latent factor). This could be followed by post-estimation procedures to examine equation-level and global goodness of fit. Following, the model could be respecified with second-order factors: Transformative experience, transformative learning, and ecological identity, each as latent

factors of the 10 subscales (Figure 12). This could again be followed by post-estimation procedures. To compare the two models, a chi-square difference test, and comparison of Akaike's and Bayesian information criteria outputs for each model, would reveal if the latter was the more parsimonious model, as expected, since the compiled instrument is composed of three different, validated instruments.

Figure 12

Second Order Confirmatory Factor Analysis Model for Future Research



Another direction of study could be towards instrument development. Anecdotally, I noticed that many of the students answered long strings of the same answer on the TEQ tool. The

next study could consider modifying that tool or using another tool to measure students' TE, to include negatively phrased prompts and a reduced number of similar prompts (Appendix E). My study also indicated correlation between shifts in TROPOS and EIS scores, though they did not directly mirror each other. If *identity shifts* are a valid definition of transformative learning (Illeris, 2014), the development of an instrument that combines the TROPOS and EIS instruments could be valuable to use in ongoing research in this area. As Cox (2021) stated about his TROPOS instrument, it is "intended to be enhanced and expanded through both new and revised subscales operationalized from other theoretical perspectives within TL" (pp. 384–385). A tool that measures shifts in transformative learning through shifts in identity, and ecological identity in particular, would be helpful in examining the effectiveness of teaching interventions towards education on sustainability and the environment.

The mechanisms behind the interactions of these three constructs were not explicitly explored, since this was a naturalistic study meant to gather baseline data and introduce overlapping constructs. A large sample, experimental or quasi-experimental study could be designed to test mechanisms (Shadish et al., 2002). A powerful course design would be to include both teaching for transformative experiences in science (TTES) interventions and TL andragogies (e.g., extra-rational and premise-reflecting activities) to increase the likelihood of centralizing learners' ecological identities (Figure 3). TE could encourage students to see the relevance and value of using ecological principles in their everyday lives so that they are willing to spend the extra cognitive energy and time reflecting on their previously unexamined meaning perspectives and nature-based identities. This examination would then lead to TL and center-shifting of their ecological identities which has been shown to impact their behaviors. Adults with ecological identities that are more central to their sense of self would theoretically make

decisions and behave in ways that verify that identity – that is, consider the well-being of themselves, others, and the ecosystems of which they are intertwined (Burke & Stets, 2023; Walton & Jones, 2018).

This study setup would require the recruitment of instructors willing to be trained in transformative teaching methods and to make alterations to their course design (for the randomly assigned intervention sections). Sections would be randomly assigned to either a comparison group (teaching ecology as normal), or groups that implement TTES, TL methods, or both TTES and TL methods in the ecology units of the course. Results of this study could more clearly answer questions about the impacts of TE and TL alone versus their use together, in providing students TE, TL, and ecological identity shifts.

Finally, expanding this study setup to other contexts could provide valuable information. This could be implemented with STEM or even sustainability majors, in graduate education, or in informal educational settings. For instance, what transformative techniques could a trainer or teacher use in informal science education (zoo events, museum programs, science cafes) or during staff training at companies with sustainability tenets to impact learners' ecological identities? Further research across contexts could continue to answer important questions in the field: Do transformative experiences accumulate to result in transformative learning and ecological identity shifts (Heddy & Pugh, 2015)? What is the tie between learners' ecological identity shifts and their long-term pro-nature behaviors (Rahmani et al., 2022; Udall et al., 2021)? How do individual and collective ecological identity shifts relate to changed behaviors (Dibattista, 2022; Hayes-Conroy & Vanderbeck, 2005; VanWynsberghe, 2022)?

Conclusions

Unsustainable human behaviors have led to global challenges due to climate change, food

systems, and rising ocean levels. Behavioral shifts are needed to adapt to these new challenges to our species, and identity shifts have been proposed as the best predictor of the necessary pro-nature behaviors. This dissertation research proposes a framework to use in higher education, and beyond, to accomplish this goal: Focus on providing transformative experience towards enhancing student transformative learning shifts that can lead to centralizing of students' ecological identities. This centralized ecological identity would then drive longer-term, pro-nature behaviors.

Results indicated that select cases of nonmajor introductory biology instructors in two states and three campuses included transformative goals and teaching in their classrooms. They were most likely to include transformative experience components, but all components of transformative learning were present as well. There was little focus on identity, and when present, science identity, not nature-based identities, were usually mentioned. Overall, students' transformative experience, transformative learning, and ecological identity scores were significantly higher after their coverage of ecology content than before. Path analyses revealed that student shifts in transformative experience helped mediate the impacts of their transformative learning shifts on their centralizing of ecological identities.

A second round of quantitative analyses indicated that students in all sections, whether the instructor included relatively high, medium, or low levels of transformative experience, had significantly higher post than pre scores on the TEQ. That is, these post-secondary students underwent transformative experience without explicit instructor training and inclusion of TE methods. Similarly, students in both high and low overall transformative teaching (IDT) sections had significantly higher post than pre scores on the TEQ. However, instructor inclusion of transformative learning or overall transformative teaching (IDT) goals and methods resulted in

significantly higher student TROPOS-post than TROPOS-pre scores. In addition, students in these sections had significantly higher TROPOS-post scores than the TROPOS-post scores of students in sections with less inclusion of transformative teaching.

The interactions of instructor TL-level by time and instructor IDT-level by time for the Ecological Identity Scale student scores were both nonsignificant. However, univariate analyses showed that for students in the TL-high and TL-med sections, their ecological identities were significantly higher after learning ecology content than before. For students in sections that included high levels of transformative teaching (IDT-high), their EIS-post scores were significantly higher than their EIS-pre scores. These results indicate there is a positive relationship between instructor inclusion of transformative learning methods or overall transformative teaching and students' shifts in their ecological identities.

The findings contribute to literature on TL theory, particularly its praxis in environmental education, its measurement using an existing quantitative instrument (TROPOS) in a new context, and a case to examine its definition as shifts in identity (Illeris, 2014). Similarly, for the environmental education literature, especially in relation to behavioral change, this study provides a further explanation of ecological identity shifts as the bases of long-term behavioral shifts; another context where the EIS instrument was applied; and, an argument for the integration of TE and TL strategies as integral for reaching desired learning outcomes. Finally, for learning sciences researchers, this study gives another use case of TE in the college biology classroom, provides evidence of post-secondary student TE shifts even without explicit TTES integration, and begins to uncover the relationship between TE and TL which had not yet been empirically explored.

From a practical standpoint, results introduce ecological identity shifts as a potential

outcome for the ecology unit of introductory biology courses. Though, the inclusion of such transformative outcomes must be paired with extra support for learners undergoing such impactful changes (Hoggan et al., 2017). Classroom activities of nonmajor instructors around ecology and environmental topics are mentioned, which could help other instructors achieve their desired outcomes, whether content-based or transformative. Finally, assessment tools are provided for instructors, instructional designers, and curriculum developers (TEQ, TROPOS, and EIS) to consider integrating into courses that include learning objectives around increasing pro-nature behaviors. Increased inclusion of these goals and transformative teaching methods would likely lead to both individuals and communities more ready and able to handle the current climate crisis.

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Appendix A

Qualitative Datasheet Used During Instructor Observations

Observation of: *Date/Time:* *Location:*

Categories	Count	Examples	Category
1. The instructor's sharing of how they notice(d) ecology concepts in their everyday life			TE-MU
2. The instructor's sharing of how knowing ecology concepts might change everyday experiences.			TE-CP
3. The instructor's assignment of value or relevance to ecology concepts.			TE-EV
4. The instructor's use of disorienting dilemmas or awe as a part of instruction			TL-DA
5. The instructor's creation of opportunities for students' critical self-reflection			TL-CR
6. The instructor's creation of opportunities for critical discourse			TL-CD
7. The instructor's creation of opportunities for students to demonstrate change in behavior			TL-O

Note. TE – transformative experience; MU = motivated use CP = changed perceptions; EV = experiential value; TL = transformative learning; DA = disorientation or awe; CR = critical reflection; CD = critical discourse; O = outcome (behavior).

Rubric based on the 3 categories of TE (Koskey, 2018) and on the Transformative Learning Environments Survey (TLES; Walker, 2018).

OTHER NOTES:

Examples from Walker (2018) for items 4-7:

4. In this class, the instructor…
    - …Provided students with unsettling information. …Used a different frame of reference than students would have.
5. In this class, the instructor…
    - …Asked students to think about where their ideas came from. …Asked students to reflect on their ways of thinking.
6. In this class…
    - …Students had full information. …Students felt comfortable defending their way of thinking.
7. In this class, the instructor…
    - …Helped students make any new ways of thinking obvious. …Set up situations where they could express any new viewpoints.

Appendix B

Qualitative Semi-Structured Interview Questions

Interview with _____

Date/Time:

Location:

Introduction: The goal of this interview is to better understand the ecology concepts you teach your students in introductory biology. Please think back through your lecture content and assignments related to ecology as we proceed. If sending me documents (like assignments, syllabus) would help explain responses, you can do so for my review, and they'll be held confidential as well.

1. **What do you hope students can do** if they fully participate and complete the ecology unit of your course?
2. What stories or personal anecdotes do you share with students about **your own interactions with nature** and ecosystems?
3. In what ways, if any, do you encourage students to **notice, in their everyday lives, the ecology concepts** you are covering in class?
4. Describe one or more assignments or activities that might help your students see the **value of understanding ecology concepts**.
5. Describe one or more **assignments or content in your ecology unit that you think are most surprising, upsetting, or attention-grabbing** for your students.
6. Can you describe an assignment or class activity that **deliberately challenges students' preconceived notions** about ecosystems or ecology?
    a. How do students typically react?

7. Can you give an example of an assignment that requires students to **critically examine their own environmental behaviors**?
8. Describe an assignment or activity that you think **promotes students' reflections on their role(s)** in ecosystems.
9. What types of questions do you pose to students to **stimulate deeper thinking** about their relationship with the environment?
10. Describe an assignment or activity that **gets students thinking about their identity as an ecologically-literate individual** or as a part of a multi-species community.
11. How do you **incorporate peer feedback or discussion** into your ecology assignments?
12. Do you have any examples of **how you facilitate deep dialogue** among your students about ecological concepts or issues?
13. How do you design group activities to **promote diverse perspectives and constructive debates** on ecological topics?
14. What assignments or activities during your ecology unit **motivate students the most to behave differently** towards ecosystems?

Appendix C

Sample Page of Instructor Interview Transcript

Interview of Maggie

Date/Time: 12/5/2024, 9:36AM

INTERVIEWER: Describe how you feel like you encourage students to reflect deeply on their role. What are the prompts? You've told me that you have them reflect and do these one-pagers? What are the prompts you're asking them to help reflect?

MAGGIE: The kind of questions I ask in response to assignments like the ecological footprint are: “What do you think your responsibility is towards the planet? What do you think your responsibility is to other people in your community for making these types of decisions? What kind of responsibility do you think you have to yourself to affect the world around you to be a certain way the way you want it?” It's more about personal responsibility towards different entities than... Is that what you're looking for in terms of the question you're asking me?

INTERVIEWER: Yeah. Yeah. So that's the prompts that really get them reflecting?

MAGGIE: Yes. The flip side of that is what is their personal responsibility, but also is it again, moral, legal, ethical for them to impose that responsibility on other people in terms of changing laws, speaking up, you know? Is that something they should do or shouldn't do? They need to answer that question for themselves.

INTERVIEWER: Yeah, that's a good addition.

MAGGIE: That's the other part of what I asked them.

Appendix D

Deductive Codebook of Instructor Interviews

Transformative Experience

Motivated use

The learner notices or is (intrinsically) motivated to use a concept they learned in class, outside of class. Pugh says that it must not be because of a requirement to do so; they are applying a newly learned concept of their own volition and free-will. Heddy says that even if their motivation is extrinsic (e.g., assigned homework), this is still the learner being motivated to apply the concept outside of class, so it also counts.

Changed perception

The learner changes the way they see everyday objects, events, and issues with the lens of this new concept. The learner is expanding their perceptions, or mental constructs that they have previously formed to make sense of situations.

Experiential value

The learner now values the content for its usefulness in everyday experience. This valuing sits at the overlap of interest, perceived usefulness, and feeling.

Transformative Learning

Disorientation

Or awe. The learner observes, learns, or realizes something that doesn't fit with their existing worldview/identity. It may be upsetting, frustrating, or surprising to the point it shakes them. They can choose to ignore it or move on to critical reflection to confront this previously unexplored assumption/worldview.

Critical reflection

Reflections on the "why" questions - they are examining their own and other's assumptions, as well as previously unexamined systems of power or oppression that may require revolutionary change. This reflection (rationally) or soul work (extra-rationally) puts learners in an uncomfortable, liminal space, just like with identity interruptions, which means it requires tools, supportive social connections, and motivation to work through.

Critical dialogue

This is the sharing of critical reflections with others - not about content, but about the learner's struggles, ah-ha moments from reflecting, or describing their shifting of perspectives/identities and what it means for their life. Setting up an environment where diverse voices feel safe speaking is an important precursor to this ("social support" in Cox's TROPOS).

Expanded perspective

The learner, after reflection and dialogue, now has a permanent shift in worldview, perspective, identity. They now see the world, and themself in the world, differently, and will seek to act out this new perspective/worldview (to "test it")

Identity

Nature Identity

Ecological identity - a type of person identity that or more central than partial identities which are based on work, family, etc. How the individual sees themselves as part of nature (and thinks others see them as part of nature)

Science Identity

Role-based partial identity (e.g., environmentalist identity, identity as a biologist, identity as a scientifically literate citizen)

Appendix E

Combined Survey Instrument Used in Study

Pre-Survey: As you answer the following questions, think about ecology topics you have learned about in the past and so far in your Introductory Biology course. Completing this survey takes about 15 minutes, on average. Please read prompts carefully.

Post Survey: As you answer the following questions, think about the ecology topics you covered in your introductory biology course - from populations to communities to ecosystem levels. Completing this survey takes about 15 minutes, on average. Please read the prompts carefully.

#	Prompts	Source	Type: Subcategory
	I am someone who…	Ecological Identity Scale (Walton & Jones, 2018)	
1	Is aware of and cares about my impact on the environment	EIS	Sameness (EIS-S)
2	Is strongly connected to nature and the environment	EIS	EIS-S
3	Is a protector/nurturer of wildlife and their habitats	EIS	EIS-S
4	Others view as being an environmentalist	EIS	EIS-S
5	Views myself as an environmentalist	EIS	EIS-S
6	Is trying to be a better environmentalist	EIS	EIS-S
7	Identifies with big business and corporations [r]	EIS	Differentiation (EIS-D)
	I identify with people who…		
8	Make significant changes in their lifestyle for environmental reasons	EIS	EIS-S
9	Feel they have the right to consume as much as they want [r]	EIS	EIS-D
10	Don't care about their environmental impacts [r]	EIS	EIS-D
11	Doubt global warming is happening [r]	EIS	EIS-D
12	Doubt global warming is mostly caused by humans [r]	EIS	EIS-D

	Use the 4-point Likert scale from,* Strongly Disagree *to* Strongly Agree*, to select the answer that best describes your response to the prompts.	Transformative Experience Questionnaire (Koskey et al., 2018)	
13	I **communicate** with other students in my class about ecology concepts.	TEQ	Motivated Use (TEQ-MU)
14	Outside of school, I **talk** with others about ecology concepts.	TEQ	TEQ-MU
15	I **talk** with others about ecology concepts just for the fun of it.	TEQ	TEQ-MU
16	While studying for ecology, I **think** about how ecology concepts apply to real-world objects and events.	TEQ	TEQ-MU
17	Outside of school, I **think** about ecology concepts.	TEQ	TEQ-MU
18	I find myself **thinking** about ecology concepts in everyday situations.	TEQ	TEQ-MU
19	I **apply** the knowledge I've learned about ecology while completing course requirements.	TEQ	TEQ-MU
20	Outside of school, I **apply** the knowledge I've learned about ecology.	TEQ	TEQ-MU
21	I **apply** the stuff I've learned about ecology even when I don't have to.	TEQ	TEQ-MU
22	I look for chances to **apply** my knowledge of ecology in my everyday life.	TEQ	Experiential Value (TEQ-EV)
23	I **think** about things differently now that I have learned about ecology concepts.	TEQ	TEQ-EV
24	In other courses, I **notice** examples of ecology concepts.	TEQ	TEQ-EV
25	If I see a really interesting ecological interaction (either in real life or through media, like videos), then I **think** about it in terms of ecology concepts.	TEQ	TEQ-EV
26	The ecology concepts I learned in my biology class changed the way I see the world.	TEQ	TEQ-EV
27	I can't help but see the world in terms of ecology concepts now.	TEQ	TEQ-EV
28	I notice examples of ecology in my everyday life that I would not have noticed before taking biology.	TEQ	TEQ-EV
29	Outside of school, I look for examples of ecology concepts.	TEQ	TEQ-EV
30	Learning about ecology concepts is useful for my future studies or work.	TEQ	TEQ-EV

31	Ecology concepts help me to better understand the world around me.	TEQ	Changed Perception (TEQ-CP)
32	Knowledge of ecology concepts is useful in my current, everyday life.	TEQ	TEQ-CP
33	I find that ecology concepts make my current, out-of-school experience more meaningful and interesting.	TEQ	TEQ-CP
34	Ecology concepts make my everyday experience more interesting.	TEQ	TEQ-CP
35	While studying for my biology course, I find it interesting to learn about ecology concepts.	TEQ	TEQ-CP
36	I think ecology is an interesting topic.	TEQ	TEQ-CP
37	In this course, I find it interesting when we learn about real world examples of ecology concepts.	TEQ	TEQ-CP
38	I am interested when I hear things about ecology concepts outside of school.	TEQ	TEQ-CP
39	Outside of school, I find it exciting to think about ecology concepts.	TEQ	TEQ-CP
	[pre-test] ***During my prior learning about ecology in my biology class(es)...*** *[post-test]* ***While I was learning about ecology in Introductory Biology…***	Transformative Outcomes and Processes Scale (Cox, 2021)	
40	My fellow students often made an effort to understand my perspective	TROPOS	Transformative Process - Social Support (TROPOS-S)
41	I usually felt safe sharing my opinions	TROPOS	TROPOS-S
42	I could raise questions about my fellow students' beliefs without fear of being shut out	TROPOS	TROPOS-S
43	My fellow students and I supported one another	TROPOS	TROPOS-S
44	Group discussions were usually inclusive of differing perspectives	TROPOS	TROPOS-S
45	I trusted my fellow students	TROPOS	TROPOS-S
46	My fellow students and I respected one another	TROPOS	TROPOS-S
47	I felt it was safe to participate in the group as my authentic self	TROPOS	TROPOS-S
48	I felt comfortable suspending my judgment	TROPOS	Transformative Process - Attitude toward uncertainty (TROPOS-U)
49	I was open to new possibilities	TROPOS	TROPOS-U
50	I often felt hesitant in what I believed to be true	TROPOS	TROPOS-U

51	I benefited from suspending my judgment	TROPOS	TROPOS-U
52	I often felt surprised by what I learned	TROPOS	TROPOS-U
53	I found discomfort could be an important part of learning	TROPOS	TROPOS-U
54	I found stepping outside my comfort zone helped me learn	TROPOS	TROPOS-U
55	I often felt uncertain about my beliefs	TROPOS	TROPOS-U
56	I was willing to explore ideas I disagreed with	TROPOS	Transformative Process – Criticality (TROPOS-C)
57	I discovered contradictions in my beliefs	TROPOS	TROPOS-C
58	I challenged my own beliefs	TROPOS	TROPOS-C
59	I challenged my fellow students' beliefs	TROPOS	TROPOS-C
60	My fellow students raised questions about my beliefs	TROPOS	TROPOS-C
61	I explored new ways to think about my beliefs	TROPOS	TROPOS-C
62	Disagreements helped me understand my beliefs	TROPOS	TROPOS-C
	[pre-test] ***As a result of my prior learning about ecology...*** *[post-test]* ***As a result of the ecology topics covered in Introductory Biology...***	TROPOS	
63	My deeply held beliefs changed	TROPOS	Transformative Outcomes (TROPOS-O)
64	I developed a greater sense of responsibility toward others and the environment	TROPOS	TROPOS-O
65	I changed my goals for the future	TROPOS	TROPOS-O
66	I made major changes in my life	TROPOS	TROPOS-O
67	My view of myself changed	TROPOS	TROPOS-O
68	My view of the world changed	TROPOS	TROPOS-O
69	My life has been changed	TROPOS	TROPOS-O
	Use the 5-point Likert-like scale, from* Not at all *to* Very*, to select the answer that best describes your response to the prompts.		
70	How likely are you to discuss wildlife, nature or environmental issues with **classmates or co-workers**?	EIS	Centrality (EIS-C)
71	How likely are you to discuss wildlife, nature or environmental issues with your **friends**?	EIS	EIS-C
72	How likely are you to discuss wildlife, nature or environmental issues with your **family**?	EIS	EIS-C

73	How close are you to people who want to protect and preserve the environment?	EIS	EIS-C
74	How large of a role does protecting and preserving the environment play in your life?	EIS	EIS-C
75	How large of a role do these activities or actions play in the ideal person you strive to be?	EIS	EIS-C
	Characteristics		
	Name:		
	School ID#:		
	Age:		
	Academic Major(s):		
	Academic Minor(s):		
	Gender Identification: *Male, Female, Non-binary/third gender, Prefer not to say*		
	Which race or ethnicity best describes you? *White, Black or African American, Latine, American Indian or Alaskan Native, Asian, Native Hawaiian or Pacific Islander, Middle Eastern, Multiple ethnicities or races, Other, Prefer not to say*		
	What is your classification: *Freshman (completed 0-29 credits), Sophomore (30-59 credits), Junior (60-89 credits), Senior (90+ credits), Graduate Student, Other*		

Note: [r] denotes responses that were reverse-coded