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The role of ethical care in the geosciences: examining the perspectives of geoscience undergraduates

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ABSTRACT

Training students to become ethical geoscientists has generated significant interest, particularly when confronted with the need to consider geoscience practice in light of geo-technological advances and environmental issues associated with resource extraction, pollution, and climate change. In this research, we examine from the perspective of student geoscientists what it means to be an ethical geoscientist. As part of a sedimentology course that explicitly taught ethics through experiential learning, students reflected on what it meant to be an ethical geoscientist. The student reflections ($N = 37$) collected at the beginning and end of the semester were analyzed using thematic analysis and interpreted. We used an ethics of care framework to generate three themes which described attentiveness to care, responsibility for care, and competency to provide care. First, attentiveness to care described the act of recognizing one's own need and the need of others and making intentional efforts to address those needs. Student reflections revealed that attentiveness to one's integrity and reflecting on one's own actions in their interactions are important characteristic of an ethical geoscientist. Second, responsibility for care described the recognition of the need to care for the things with which we interact. Students described that being responsible for societal and environmental needs, such as promoting scientific literacy and guarding other species, are the hallmarks of an ethical geoscientist. Finally, competency to provide care described the availability of effective knowledge, skills, and materials to ethically provide care. Student reflections captured competencies related to scientific practice in ensuring data precision, accuracy, and maintaining caring and ethical relationships with colleagues as ethical geoscience characteristics. We suggest instructional strategies that explicitly teach ethics and critical reflection to foster students' sense of care and interest in geology both as a science and ethical practice.

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Geoethics; ethical care; ethical reflection; undergraduate geoscience education

Introduction

The extensive use of geo-resources, such as minerals and water, calls for practices that will promote sustainability (Gosselin et al., 2013). Other potentially destructive interactions between humans and Earth, such as mining, use of fossil energy, and settlement development also suggest significant need for effective approaches to sustainability and environmental protection to reduce the harmful repercussions that such usage and interactions have on both biotic organisms and the environment (Firozjaei et al., 2021; Hellqvist, 2019; Kartal, 2022). As described by Peppoloni and Capua (2015), these interactions between humans and the Earth are complex ones that raise ethical issues, such as degradation of the world's freshwater and biological systems, destruction of forests, wetlands, oceans, and the long-range transportation of harmful compounds. Hence, we need to consider our responsibility in our interactions with nature if we are to understand the Earth, mitigate negative anthropogenic impacts, and find sustainable ways to live within the limits of the planet's resources (Mogk, 2018; Peppoloni et al., 2019).

Geoethics places a strong emphasis on the requirement for scientific objectivity, as well as the adoption of suitable methodological and sociocultural practices that require collective responsibility to care for the Earth (Martinez-Frias, 2008). In recent years, the discussion of ethics within the geoscience community has generated significant interest, particularly when confronted with the need to consider geoscience practice in light of geo-technological advances and environmental issues associated with resource extraction, pollution, and climate change.

Some geoscientists have suggested that one way to protect the Earth is to cultivate learners' commitment to sustainable futures through the explicit teaching of geoethics (Mogk & Bruckner, 2020; Mogk et al., 2017; Peppoloni et al., 2019). Peppoloni and Di Capua (2016) argue that geoethics education could potentially foster ethical practices toward the

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environment by raising awareness about how humans affect the Earth. Geoethics encourages students to become fully aware of their role as active participants in the Earth's processes and to accept the ethical responsibilities associated with such a role. The use of instructional approaches that incorporate geoscience principles that heavily includes geoethics and authentic learning (Mosher & Keane, 2021) may have a positive influence on students' ability to make decisions about ethical issues and to adopt ethical behaviors (Peppoloni et al., 2019). Authentic geoscience learning involving endeavors and activities that integrate real-world problems and data, sense of place, as well as the significance and value of cultural validity (Kastens & Krumhansl, 2017; Semken et al., 2017; Sorge et al., 2022; Williamson et al., 2022) will not only help students to construct content knowledge and practice technical skills, but it also has the potential to affect students' ability to make decisions about ethical issues and to adopt ethical behaviors.

The growth of students' ethical capacities is also relevant to workforce development. For example, Nyarko and Petcovic (2022) found from environmental and hydrogeology employers that ethical values related to trust, humility, and integrity are essential teamwork skills required to build an effective workforce. Similarly, Mosher and Keane (2021) identified ethical awareness and conduct relating to being responsible, dependable, and honesty as important workforce skills that students need to develop. According to Almeida and Vasconcelos (2015), geoscience students are likely to be unfamiliar with geoethics though they recognize the relevancy of having ethical guidelines for geoscience research and practice. However, in a recent study, Keane and Asher (2021) asserted that while students remain largely unacquainted with the breadth of geoethics, this can be corrected by exposing students to practical opportunities to apply geoscience knowledge in solving ethical issues, and providing consistent support from geoscience faculty and employers.

In order to improve geoscience students' ability to understand geoethics and navigate ethical issues, it is necessary to foster geoethical competency among students through explicit instruction. By explicit instruction, we mean lessons that specifically include ethics as learning and teaching outcomes and provide opportunities for experiential assessment through students' critical reflection. There is also the need for students to be exposed to ethical reasoning and decision-making practices (Davis, 1999; Sternberg, 2010). Effective ethical preparation of students has the potential to help them develop accurate conceptual connections between science, environment, and society (Sadler, 2004; Sadler et al., 2006). However, our review of the geoscience education literature indicates that no research has explored student's geoethical reasoning during instruction that explicitly connects geoscience content and ethics. This study adds to the ongoing conversation about potential opportunities in fostering the development of ethics as part of geoscience content knowledge.

We employ Tronto's (1993) formulation of an ethic of care as our theoretical framework to examine the geoethical thought and practice of students during geoscience inquiry. Tronto's framework suggests four elements of care, including attentiveness, responsibility, competency, and responsiveness. An ethic of care framework has proven to be useful in both ethics and education research. For example, Feldman (2020) identified the need for faculty and institutions to promote experiences of connection and interaction for students to feel a sense of care. Bozalek et al. (2014) used an ethic of care theory to evaluate teaching practices in a professional development program and identified that as people act responsibly, their trust for what they do improves. The purpose of our study is to examine how students articulate care for the environment, society, and their own selves as they complete an assigned experiential activity — fieldwork and reflective essays in a sedimentology course.

Literature review

Conceptualization of geoethics

There are variety of ways in which ethics has been conceptualized and operationalized. According to Weston (2007, p. 5), "ethics is a concern with the basic needs and legitimate expectations of others as well as our own." In other words, we can think of ethics as being concerned with the ways we co-fashion our lives, the lives of others, and our shared world according to our values. Hence, the governance of both ourselves and others, as well as the broader systems that comprise society, is a fundamental ethical matter.

As in other disciplines, ethics in the geosciences are often articulated through a series of codified standards and written statements that describe the conduct expectations for members of the issuing group (Abbott, 2017). For example, the American Geophysical Union (AGU), Geological Society of America (GSA) and other geoscience organizations have code of ethics that members must adhere. Geoscientists are also bound by unwritten codes guided by personal and professional morality in our interactions with society and the geosphere (Almeida & Vasconcelos, 2015; Peppoloni & Di Capua, 2016). Our ethical actions "should reflect, among other things, freedom, scientific and professional skills, integrity and good practices, reflection, socio-cultural and human dimension and principles and motivations" (Martínez-Frías et al., 2011, p. 257). These ethical expectations obligate geoscientists to have possession of particular ethical knowledge that has implications for the general public, which fosters integrity, honesty, and dependability (Abbott, 2017; Peppoloni & Di Capua, 2016; Wyndham et al., 2015). Hence, geoethics is mostly conceptualized as written statements upon which geoscientists base appropriate behavior and practice (Abbott, 2017; Peppoloni & Capua, 2015) consisting of appropriate protocols and codes of good practices to shape our understanding of the human and more-than-human parts of our society and environment (Martinez-Frias, 2008).

The origin of the term geoethics continues to be a debatable venture between geoscientists and environmental scientists. Whereas geoscientists consider the term to be born in the early 1990s, environmental scientists suggest the term

was first coined in the 1960s in a move to extend ethical concern to soils, water, and land (Almeida & Vasconcelos, 2015). However, Martínez-Frías et al. (2011) assert that geoethics became an independent research field around 1992 in an effort to apply ethics to Earth Science practice and research. In the past three decades, geoethics and its associated social implications have become indispensable for geoscience research, practice, and training (Peppoloni & Capua, 2015). For example, the International Association of Promoting Geoethics [IAPG] (2012) emphasizes that geoethics consists of those values that represent an opportunity for geoscientists to become aware of their social responsibilities in conducting scientific investigations. They further suggest that geoethics should foster an awareness of geoscience communities regarding problems related to geological resources and the environment.

Fore and Hess (2020) provide an "ethical becoming" framework within which geoethics can be contextualized. Ethical becoming is premised on the notion of a relational process ontology, meaning that the "being" of a given subject is perpetually achieved through a constant process of becoming. Reality is, therefore, fundamentally relational. For example, humans are fashioned through and due to their relationships with both human and more-than-human subjects, like the Earth. This produces the experience of indebtedness (Nyamnjoh, 2017), which in turn, makes our present encounters ethically significant and rich with expectations, commitments, responsibilities, and trust. This is relevant to the geosciences, as the Earth, for which we desire to be stewards, is constantly becoming through relational processes.

Due to their capacity for reflective thought, humans grow their abilities to critique their own thoughts and practices, as well as the shared problems born from their relationship with the Earth system. In the ethical becoming framework, Fore and Hess (2020) argue that such critique is beneficially guided by ideals and values related to beauty (i.e., harmony and potency) and an ethic of care, which, respectively, provide a direction for growth and a set of moral excellencies capable of animating one's inquiries and interventions into the complexities of one's immediate context. This relational process is clearly contextual and, therefore, what may be ethical conduct in one situation may be abhorrent in others given differing value systems (Frankl, 1992). This means that ethical conundrums rely on the viewpoints and real-life experiences of individuals, who may value different things. Hence, personal, historical, and cultural aspects also have a lot to do with what is ethical.

Bohle (2021) provides six categories of geoethical rationales based on the human-niche in which geoethics is related to various ethical norms: actor-centric, virtue-ethics focused, responsibility focused, knowledge-based, all-actor inclusive, and universal-rights based. First, actor-centric refers to the application of established frameworks that empowers the group to act their best in the face of given circumstances and purposes. This rationale suggests that group members must always avail themselves to the accepted ethical practices within the group irrespective of circumstances. For example, each member of the geoscience community is an important ethical actor in ensuring the sustainability of Earth in the face of climate change and environmental injustice. Second, virtue-ethics describes personal traits that affect the capabilities of group members to develop and govern individual and collective conduct. Through personal traits, such as honesty, integrity, reliability, and cooperation, they carefully and justly manage the human and material resources of the group. One develops a given virtue, which, in Aristotelian virtue ethics, exists as an ideal mean between two vices. Through practice, a virtue is ideally developed to the limit of perfection, and, in such a state, virtuous subjects may excel at governing themselves and others. Both actor-centric and virtue-ethic rationales give relevance to human actors within the geoethics process.

Third, responsibility-focused rationale is concerned with the analysis of the outcomes of group actions, particularly in terms of accountability and the implications of unintended consequences for future generations. For example, the geoscience community should take a responsibility rationale and be ethically concerned with issues that put the Earth and its inhabitants in danger. Fourth, the knowledge-based rationale describes the levels of knowledge within a group. It implies that in geoethics, primary and secondary knowledge acquired through scientific preparations and experiences serve as the basis for knowledge reproducibility and verification. Bohle (2021) asserts that responsibility-focused and knowledge-based rationales provide opportunities to develop ethics through established and shared actions. Finally, all-actor inclusive and universal rights-based rationales call for community participation and refer to the ethics of equity or justice. The all-actor inclusive rationale refers to the practices of participation, capacity building, and mitigating power differences within contexts where operational responsibility is shared between various groups. The universal-rights based rationale guides the groups' collaborative, affective, and rational sense-making to strengthen group effectiveness. With a universal rationale, the group navigates around constructs, such as utilitarian, sustainability, or precautionary principles to manage ethical standards.

Research on geoethics in higher education

Higher education has been identified as one of the major champions to develop the state of geoethics in the geosciences. As described by Peppoloni and Capua (2015, p. 7),

> For geoscientists, cultural and practical preparation has to take on an ethical dimension, starting at the university level. Through their individual commitment, young geoscientists can assume the need for continued cultural education as an ethical duty.

Researchers have emphasized the role of geoethics in maintaining the professional standards of geoscientists. They suggest continued geoethics education in the classroom for students, and in professional development programs for instructors (Mogk & Bruckner, 2020). This call is based on the notion that geoscientists can play a key role in supporting society by ethically developing and promoting tools that may mitigate the impact of human activities on Earth and

deal with the environmental challenges that face humanity (Peppoloni & Capua, 2015). Also, there is a close connection between ethical decision-making and critical thinking across the curriculum. They both employ higher-order thinking skills in the cognitive domain, and also are impacted by aspects of the affective domain. All require analysis based on evidence, prioritization of evidence, and ultimately making choices that permit further action.

However, geoethics continues largely to be absent from the curriculum of geoscience courses, despite educator recognition of the importance of teaching geoethics from an early age and throughout elementary to university curricula (Almeida & Vasconcelos, 2015; Mogk et al., 2017; Vasconcelos et al., 2016). This limits the effort to prepare ethically trained students. As described by Bohle (2021), training students in geoethical thinking—including critical reflection on moral adequacy and responsibility—strengthens the operational guidance related to geoethics. The few studies that have investigated geoethics in higher education have provided mixed results regarding students' perceptions. Georgousis et al. (2021) identified that university students perceive the need for geoethics to be applied to environmental protection; however, they also perceive the environment as containing renewable capital that humans should explore. Similarly, Almeida and Vasconcelos (2015) identified from students that geoscience practices should be guided by a code of ethics and that they should learn that it is an ethical responsibility for geoscientists to participate in political decisions that affect the Earth. In summary, both the geoethics literature and education literature suggest explicit incorporation of ethics into students' preparation in higher education.

Theoretical framework

An ethics of care (Tronto, 1993, 1998) is generally recognized as a robust and accessible conceptual framework of ethics. It emphasizes that all human beings and their world need, receive, and give care to others. Care is a complex word with so many dimensions, such as: 1) care as concern, 2) care as sensitivity to the vulnerability and/or anxiety of care recipients, 3) care in attention to details/practices, and 4) care for well-being of others. The complexity of caring practices and modes of thought is also expressed in geoethics; for example, geoscientists should care for their selves, their profession, and the responsible conduct of research, as well as their conduct pertaining to various communities and Earth stewardship. Furthermore, Mogk (2018) hypothesizes that professional ethics of care are consistent with the geoscience profession's foundational ideas of power, trust, respect, accountability, fairness, and justice.

According to Tronto (1993), care consists of activities that "maintain" and "repair" the fabric of our lives for survival in a shared world. This means that for geoscientists, care is both a practice and process aimed at maintaining or repairing our relationships with each other and the Earth—"care implies reaching out to something other than the self" and providing suggestions "that will lead to some type of action" (p. 102).

Tronto (1993, p. 106–107) suggests that for care to function, we need to 1) have the need to care (caring about), 2) assume responsibility for care (taking care of), 3) recognize and provide the care to be given (caregiving), and 4) provide a response (care-receiving). In Tronto's ethic of care, she identifies both particular acts of caring, as well as cognitive tendencies of care, that involve four elements: attentiveness, responsibility, competence, and responsiveness (Figure 1).

Attentiveness refers to the act of recognizing the need of what is around us and making intentional efforts to address those needs. According to Tronto (1993), an ethic of care posits that we have the cognitive capability to recognize needs outside of our own. We need to suspend our personal goals and concerns and concentrate on the needs of those with whom we interact. This, however, does not mean that we must fail to recognize and be attentive to our own needs for care. In attentively caring for ourselves and others, we critically inquire into the results of any care given and how our own actions affected ourselves and others. By doing this, it becomes possible to fashion our care practices in ways that lead to appropriate caregiving and care-receiving. In this regard, geoscientists need to be receptive and attentive to all human and more-than-human entities comprising the environment, so that we can recognize needs and provide care. As geoscientists, if we fail to recognize the need for caring for our environment, the Earth will be neglected, its exploitation perpetuated, and its inhabitants distressed.

Held (2006) emphasizes that the central focus of ethical care is meeting the needs of those for whom we take responsibility. Tronto (1993) argues that the responsibility for care

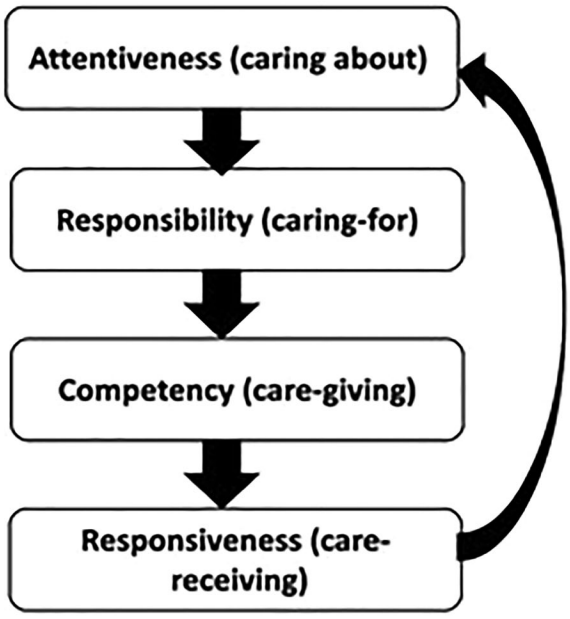

Figure 1. Hierarchical processes and stages of ethical care. The first step of care involves recognizing people's needs. After these needs have been identified, the next step is to assume responsibility for meeting them. The third step involves actually working to provide care, and finally ensuring that the recipient is responding to the care that is provided by the caregiver. The process is reiterated as care habits develop over time.

should be distinguished from obligation. She asserts that in responsibility-based ethics, actual interaction plays a vital role, whereas within obligation-based ethics, the emphasis is on a cognitive understanding of "what people should do for each other" (p. 133). For example, as a geoscientist cares for the sustainability of the Earth, they take responsibility, making a conscious choice within a particular context, rather than conforming to an external, normatively defined obligation that may or may not be relevant to the problem at hand.

Competency refers to the availability of effective resources (e.g., knowledge, skills, materials, and technologies) to ethically provide care. As described by Tronto (1993), competency is about ensuring that caring work is done effectively by people with the "know-how" to do so. As geoscientists, one way of showing competency in ethical care is by providing best practices (i.e., methods) and following through to make sure that they have actually been used. Finally, responsiveness refers to the assessment of the care plan to verify if the caring needs are adequate to address the need. For example, Tronto (1993) asserts that there has to be some form of vulnerability for one to need care; hence, we need to verify that the care given actually meet the needs of that vulnerability (what we are caring for). We must then take responsibility to care and then do so competently. The care recipient will then respond to this care. The element of responsiveness requires some level of attentiveness, because we have to consider the care receiver's responses to the care given.

The success of using an ethic of care in other areas of science and education (Groot et al., 2019; Lachman, 2012) suggests that it can be applied to the geosciences to understand the ethical care that geoscientists should practice in relation to the Earth and its resources. The framework provides a context-specific way to understand the attentiveness, responsibility, and competence of care that students enact in service to the Earth. Because we want to identify students' conceptions of geoethics and their demonstration of attentiveness, responsibility, and competence of ethical care, we define geoethics as the moral fabric that shapes our attentiveness, responsibility, and competency to foster excellence and commitment to our communities and the Earth. In other words, ethical care within the context of geoethics is concerned with how geoscientists exert considerable effort to be attentive to the needs of others and the Earth, accept responsibility to attend to those needs, competently provide care to address those needs, and maintain sensitivity to care-recipients' responses.

Purpose of study

Despite evidence supporting the importance of geoethics, research related to students' understanding and development of geoethical values remains scant. For this study, we are focused on analyzing how, if at all, elements of care animate the scientific inquiry and thinking of students within a sedimentology course. The course uses an inquiry-based teaching strategy that explicitly teaches ethics. We collected and analyzed student reflections using a qualitative descriptive design to answer the following research questions:

1. What are the perceptions of geoscience students regarding the conduct of geoscientists' in their
    a. Attentiveness to ethical problems in the geosciences?
    b. Responsibility for ethical problems in the geosciences?
    c. Competence in addressing ethical problems in the geosciences?

Methods

Research design

The study follows a descriptive qualitative study design (Merriam & Tisdell, 2016) that aims to describe students' ethical thinking through written reflections. For each student, we collected an essay at the beginning and end of a 2-day fieldwork activity in a sedimentology course that explicitly emphasized geoethics. We generated codes through thematic analysis (Merriam & Tisdell, 2016) and interpret our findings through the lens of ethics of care (Tronto, 1993).

Context of study

Integrated Community-Engaged Learning and Ethical Reflection (ICELER)

The sedimentology course explored in this study was part of an NSF-funded, institutional transformation project under the Cultivating Cultures for Ethical STEM program. The Integrated Community Engaged Learning and Ethical Reflection project, or ICELER, has aimed to transform the teaching and learning of ethics in the Earth Sciences and Biomedical Engineering departments at a large public university in the Midwest of the United States (Fore et al., 2018). Now, in its fifth and final year, the project's approach to facilitating institutional transformation has involved a 4-year faculty learning community (FLC) with members from each department. According to Price et al. (2022), the ICELER FLC's theory of change revolved around supporting faculty's professional growth, enhancement of their instructional practices, and the strengthening of their departmental cultures. This, in turn, was theorized to lead to increases in student learning outcomes related to civic-mindedness, ethical inquiry, and ethical awareness. Beginning in Year 3, FLC participants began implementing and refining their ICELER courses, which were positioned across all course levels. The data presented here is from a sedimentology course offered during the fourth year of the ICELER project.

The three key features of the ICELER framework are community engagement, critical reflection, and ethics. In an ICELER course, students should have authentic disciplinary experiences and be strategically prompted to critically reflect upon those experiences as well as any preceding experiences through an ethical lens. As the project evolved, it became clear that a narrow definition of community-engaged

learning would not suit the reality of the work faculty were doing. Over time, the ICELER team has become very flexible with how it defines communities to include human and more-than-human entities and has opened up to experimenting with multiple forms of experiential learning–creating knowledge through transformation of experience (Kolb, 2015). This includes place-based approaches (i.e., learning in a natural setting), service-learning approaches (i.e., students engage in an organized service activity that addresses identified community needs), and civic-rich approaches that use collaborative community and student problem-solving (Battistoni, 2013; Felten & Clayton, 2011; Semken & Freeman, 2008).

Sedimentology and stratigraphy course

The course being studied is a 300-level Sedimentology and Stratigraphy course offered in the Earth Sciences department at a large public university in the Midwest of the United States. There is a lab component to the course and two field trips were required. The first field trip focused on giving students the opportunity to make authentic inquiries into sediment transport at a local park and aimed to cultivate their capacity to take field notes. The second field trip gave students the opportunity to observe and record features of bedding and sedimentary structures in order to identify evolving depositional environments in an outcrop (e.g., delta, point bar, and beaches) and to further practice taking effective field notes. Reflective writing assignments in the course required students to critically consider the relationships between the ethical purposes of the geosciences, the ethical conduct of geoscientists, and their own experiences related to fieldwork throughout the semester. Critical reflection was utilized as an approach for assessing these learning objectives. Ash and Clayton (2009) describe, examine, and articulate learning (DEAL) model for critical reflection in experiential learning contexts informed how the instructor of the course designed the prompts for the reflective assessments. Within the DEAL model, instructors design reflective assessments that challenge students to *describe* their educational experiences in detail and *examine* those experiences through analytical lenses or frameworks introduced in the course. After this, students are prompted to *articulate* their *learning* by considering how this new knowledge will be applied in other experiences.

Participants

All of the 25 students in the sedimentology course received invitations to participate in the study out of which 20 gave their informed consent in accordance with the guidelines established by the study's human subjects institutional review board. Because participant information was not self-reported, we provide the demographics of all 25 students in the course as obtained from the student information database (Table 1). The course had 52% female students, 84% were white, and 10% were in the active/reserve military. Less than 50% of the students were traditional college age (18–23) and one was a parent.

Table 1. Demographic information of participants in the class.

Demographic	Number of students (%) $N = 25$
Gender	Female = 13 (52%); Male = 12 (48%)
Age	18–23 = 11 (44%); 24 above = 14 (56%)
Race/Ethnicity	Hispanic/Latino = 2 (8%); White = 21 (84%); Two or more races = 2 (8%)
College background	First generation = 4 (16%); Non-first generation = 21 (84%)

Data collection

In the course of the semester, each student wrote several reflection essays, prior to the first field trip (see Supplemental materials for prompts), as part of field notes and as part of their formal project report for the second field trip. The first essay required students to read and write a reflective essay on the IAPG (2012) ethical code and promises of geoscientists. The final essay focused on students' critical reflection of their ethical responsibilities in geoscience practice. A book chapter by Peppoloni et al. (2019) provided the lens through which students were to reflect upon their experiences. The book chapter illustrates the development of geo-ethical thought with definitions and an explanation of the values and ideas that underpin its conceptual framework and the vision of ecological humanism. Lenses used for these reflections included geoscience "interactions" and "promises." For example, students were asked to consider their geoscience experiences through the lenses of how they should interact with their own selves, their colleagues and discipline, their society, and the environment. These reflective essays constitute the data set being examined in this study. A total of 37 essays from 20 students in Fall 2020 were collected. Three students only completed one essay.

Data analysis

The unit of analysis is students' reflection essays. Because the pre-and-post reflection prompts were different, we combined each student's pre-and-post reflection essays for analysis. In this study, we conducted a thematic analysis (Merriam & Tisdell, 2016) of student reflective essays utilizing Tronto's (1993) conceptualization of an ethic of care theory, which also informed our research questions. Using our theoretical framework, and research questions, we sought to identify moments of reflective writing in which (1) students were attentive to a particular geoscience relationship and whether that relationship represented an interaction between the self, discipline, society, or environment, (2) students articulated a sense of responsibility for addressing conflicts and problems within those relationships, and (3) students identified how they should address such conflicts and problems competently. Using these themes, the first and second authors independently coded the same 22 (59.5%) student reflection essays and compared results. We then refined our codes to create a final coding scheme made up of three themes and five codes (Table 2). The codes describe the meaning of specific notions within each theme identified in the student essays. The authors independently applied the coding scheme to all the 37 student essay transcripts,

Table 2. Themes, codes, and example of quotes.

Theme	Code and definition	Example of quote representing code
Attentiveness to and Responsibility for Taking Care of Oneself and Others	Self-work/Care of the self: being a caring scientist require a great deal of work on one's own self.	*I believe it is essential for all scientists to be well balanced in their interactions with the environment, society, and their colleagues. To accomplish this equilibrium, I think the most important level of interaction comes from developing responsibility in* [attentiveness to] *oneself. I feel you have to hold yourself accountable at a high standard before asking anyone else to join your pursuit - Dan*
Responsibility for Care	Responsibility for societal needs: geoscience as a means of promoting care through scientific literacy.	*We have the responsibility of teaching future generations a better way to treat the earth, especially in the current state of things, as well as helping society understand the responsibilities it has toward the world - Alfalfa*
	Responsibility for environmental needs: care for other species and guarding against environmental catastrophes.	*I think the humankind emphasis is problematic. I agree that geoscientists should be aware of any negative societal implications, but I think a geoscientist's purpose is to protect the Earth system for the benefit of Earth not humans - Kofi*
Competency for Care	Competence connected to addressing societal and environmental needs related to one's scientific practice in ensuring data precision, accuracy, and integrity.	*A common set of ethics within the geosciences is needed in order to maintain trust… Ensuring the accuracy of information is an important part of maintaining any field of study as without honest attempts for the truth, the geosciences wouldn't be able to progress in the pursuit of truth, support society, or protect the earth - Mina*
	Competence as a care practice for discipline and disciplinary colleagues such as maintaining caring and ethical relationships with colleagues, as well as maintaining the integrity of the discipline itself.	*I took the extra time to make sure my numbers were genuine and accurate. I think this shows how holding yourself accountable first is the biggest priority, because in science it's rare for my data or results to be exclusive to me, and I wouldn't want to mess someone else up because of my mistakes - Ken*

and discussed our results (i.e., whenever there was coding disagreement on a particular text/sentence) until we achieved total (100%) agreement. To do this, we spent time to understand the manifest, latent, and contextual meaning of the sentence and then we discuss based on these meanings to assign a code. Again, throughout the data analysis, we kept annotations and memos (indexation) that helped us track questions we might have and with areas that needed further clarification. This enabled discussions throughout the analysis to establish agreement on all the applied codes. Finally, we compiled themes and codes using NVivo 20. In this article, we use students' reflection quotes that represent and explain our findings. We use pseudonyms to represent all student quotes.

Validity and reliability

Merriam and Tisdell (2016) define validity as a process of assessing the accuracy of our data. First, we verified the accuracy of our study by sharing our findings and interpretations with research associates and colleagues who are external to the research. We also engaged in independent generation of codes and comparison of interpretations during data analysis. This allowed us to capture all the important and salient ideas from the data.

We also followed Merriam and Tisdell (2016) approach to reliability as the extent to which research findings can be replicated by engaging in intercoder agreement. To calculate for intercoder reliability, we coded the same set of six students' pre-and-post essays and achieved a mean intercoder agreement of 93% which is higher than the 80% recommendation by Miles and Huberman (1994). We also engaged in communal test of reliability (Bernstein, 1983) by discussing and sharing our codes with colleagues who were not part of the research to find out if different persons may assign the same text to the same/different code. We also identified from them if the interpretations we were making are accurate. They shared no significantly different ideas to ours; hence, we did not make any changes to our coding scheme or interpretations. However, this process provided some level of validity and reliability to our coding scheme and interpretations, and helped reduce our level of bias and subjectivity.

Researcher positionality

The first and second authors are science education researchers interested in care ethics and geoethics education research. They are also a part of the ICELER team that supported faculty as they introduced ethics into their courses. We are both experts in qualitative research methods and mostly use reflections as our preferred data collection strategy. We are also predisposed to accept the notion that the only way toward a sustainable Earth is through ethical care for it and all its inhabitants. The third author is the instructor of the course and member of the ICELER cohort. Her teaching is largely informed by her ethical values for equity, respect, trustworthiness, inclusion, open-mindedness, and accuracy. Hence, we consider ethical thought and practice to be of utmost concern, and this might bias our research interpretations. Also, data was collected by the third author and analysis was completed by the first and second authors. To

identify and reduce our bias, we shared each process taken, our findings, and our interpretations amongst ourselves and other colleagues for critical review. This review helped reduce the level of subjectivity and ensured multiple perspectives in our findings and interpretations.

Interpretation and discussion of results

We organize and present our results, discussion, and interpretations in the context of our theoretical framework (Figure 1), our conceptualization of ethics, and our research questions related to the three ethical elements–attentiveness, responsibility, and competence for care. Students' reflections acknowledged that being an ethical geoscientist required a great deal of ethical care involving one's attentiveness to one's own needs and development, as well as the needs of others. Students also articulated a sense of responsibility for and competence in addressing such needs with great care. Attentiveness to personal care relates to how the students conceptualize ethics as a characteristic that borders on one's own attention to personal care. The other two themes describe the role of responsibility and one's ability to be ethical.

Attentiveness to ones' own care

Our data analysis of students' reflection suggests that paying attention to one's own self-care practices are important to be considered as an ethical geoscientist. Students described that being a caring geoscientist required a great deal of attentiveness to their own selves, which are to be monitored and brought to account for their successes, as well as their failures. Recurring topics among students were having integrity and reflecting on their own actions in their interactions with the Earth. Melina stated that

> Ethics incorporates a pact that is rooted in the integrity of oneself in respect to their personal values when conducting their work, and their commitment to their community and the Earth.

Similarly, Davis wrote that

> To be a geoethical scientist, one must constantly apply their own self-maintained check and balance system to insure a constant awareness of the problem. Having a different person do this for you not only diminishes any responsibility on the unethical scientist but also does not allow the scientist to learn and grow from their mistakes.

From a geoethics perspective, being attentive to how one values one's self ethically is important in showing care to others. Tronto (1993) proposes that it is almost irresistible to focus our concerns solely upon ourselves, but it is also reprehensible to ignore the concerns and needs of what is around us. The students in our study asserted that engagement in behaviors that serve to maintain and promote care of oneself is important in providing care for others. When they are able to ethically care about their own actions, they begin to develop the capacity to shape their responses carefully and critically to the needs of their environment and the Earth. In addition, this closely aligns with the relationship between ethical decision-making and critical thinking; by highlighting features of the cognitive domain, this can be equated to self-monitoring and self-regulating behaviors. These findings are consistent with Shapiro et al. (2007) that being attentive to one's own care and having self-compassion increases students' care and compassion for other people.

Responsibility for care

Tronto (1993) argues that ethically caring for our environment and the Earth is situated in our sense of responsibility–the need to care for the things with which we interact. She proposes that elements of ethical care should be immersed in the context of responsibility. In their reflective writings, our participants revealed two ideas related to ethical responsibility: responsibility to the society and to the Earth. Many students perceived that a geoscientist's responsibilities to society are educational or informative in nature and that the scientific knowledge they construct should be used to inform human interactions within their society. In this vein, Dan stated:

> We have the responsibility of teaching future generations a better way to treat the earth, especially in the current state of things, as well as helping society understand the responsibilities it has towards the world.

Similarly, Mina reflected on the importance of being ethically responsible in conducting scientific work to meet societal needs and knowledge. Mina wrote:

> A scientist is responsible to society. Everything that a scientist does in their work has societal implications, especially if their work is to benefit the society's knowledge.

Both Dan and Mina infer that scientific practices of keeping information from members of society are ethically irresponsible. Rather, the sharing of scientific knowledge was necessary if humanity was to be successful in carefully addressing societal needs related to the sustainability of the planet. Another student, Kim, demonstrated similar ideas as Dan and Mina when she wrote: "sharing your knowledge is one of the most important traits any scientist should have."

In the second variance of ethical responsibility, students described a range of responsibilities toward environmental needs. Students expressed concern over balancing societal needs with the needs of the planet. Here, a geoscientist had to take responsibility for the care of other species and guard against environmental catastrophes over which humans have had a considerable impact. Many participants viewed the responsibility for caring for other species as essential. Several comments, such as Zuma's, described taking responsibility for fostering sustainable mindsets:

> I want people to have better lives, but I don't believe for a minute that the other species found on our planet should be forgotten. They have to be sustained and be properly cared for [sic].

Latoya took this line of thought further when she emphasized the need for humanity to "protect nature for nature."

Chris added an additional dimension to this theme when argued that geoscientists need to strive to make the Earth better by reducing harmful anthropogenic practices from the past. According to Chris, this means that since humans "have the power to permanently alter life and create mass extinctions," then humanity must become "guardians" of the planet and try to "correct past mistakes."

These responsibilities for societal and environmental care were often conceptualized by students as being related to the communication of geoscience knowledge and practices to promote public literacy and understanding of humanity's responsibilities toward the world. This finding is consistent with the call by students that protection and exploration of the Earth must be an ethical concern for geoscientists, and that it is a geoethical responsibility for geoscientists to participate in decisions that affect the Earth (Almeida & Vasconcelos, 2015; Georgousis et al., 2021). Persistent connection of science to society is critical to developing ethical care within our social environments (Wyndham et al., 2015).

Competence for care

The care students wished to provide to society and the environment often took shape in terms of competence, particularly in regards to the precision, accuracy, and integrity of their data collection efforts. For many of the students, being a geoscientist required a deep concern for competence in one's scientific practice, since this competence was central to how a scientist cares for society, the planet, and their discipline. For example, Kevin stated:

> I had to push myself out of my comfortability to obtain the best representative samples of the sample site. Many times, a scientist may be oblivious to these actions, but it is their responsibility to check in with themselves to remain ethical and able to deliver the right information to the community.

According to Kevin, an ethical geoscientist needed to remain aware of the appropriateness and rigor of their methodological activity, because doing so ensured the construction of legitimate knowledge for the community.

Several student reflections also highlighted competency in terms that evoked honesty, trustworthiness, and truth-telling. For example, Alfalfa asserted that honesty is of the utmost importance to "science and discovery as a whole." According to Alfalfa, honesty is so important because geoscientists must keep the public informed about the "truth of the world they live in." If geoscientists are perceived to not be trustworthy, their message could be dismissed by the public. Relatedly, York wrote:

> Your work is only as good as the intent behind it, and without intellectual honesty in all geoscientific research we break our responsibility to the environment…When data is skewed…it is changed and therefore cannot be applied outside of a laboratory setting. As all geoscientific research is to provide knowledge not only to the scientific community but to the public that is able to benefit our environment, you are stripping that away.

Here, York is directly connecting honesty and the competent conduct of science to the keeping of one's responsibilities to the environment. If one fails to competently collect and analyze data due to dishonesty, one undermines the ability of the geoscience community to utilize one's data and findings to further understand environmental/ecological phenomena and to publicly apply such knowledge to the end of addressing environmental and societal needs.

Finally, as was hinted at in York's quote, there was considerable emphasis on competency in inscriptions (field notes) related to the maintenance of caring and ethical relationships with colleagues, as well as the integrity of the discipline itself. Several comments related to the taking of accurate, clear, thorough, and precise fieldnotes. Ham reported that being able to competently take fieldnotes was key.

> Being able to make notes with information and images a third person would be able to understand is something that I haven't had much experience with until this semester. While I wouldn't say I was good at it, I definitely recognize why this is an important skill to learn, especially in the Geosciences as more and more of my work is shared to others outside of just my professors.

Similarly, Dina stated that taking complete field notes is important in ethically communicating science findings:

> Taking complete field notes includes drawing field sketches and values like communication with field partners. This will help me communicate my findings and share them in writing. Communication is an essential value in the science community. Field partners must communicate findings and share field notes.

Gill reflected that if one falls short in their disciplinary competency, this could have an impact on how geoscientists can care for both society and the earth.

> I took the extra time to make sure my numbers were genuine and accurate. I think this shows how holding yourself accountable first is the biggest priority, because in science it's rare for my data or results to be exclusive to me, and I wouldn't want to mess someone else up because of my mistakes.

Tronto (1993) argues that care should be competently provided once one has taken responsibility for the giving of care. Our participants described that competency in ethical data collection was built upon precision, accuracy, and integrity. Students also reported that interpretative and iterative syntheses of observations and information were important geoscience ethical characteristics that they had to practice as they collaborated on collecting observations in their field notes. If one's field notes were incompetently collected, then one's collaborators would have difficulty proceeding with a rigorous study, and the results of the study may end up being unreliable. Without good data, the application of the research in addressing societal and environmental problems would be impossible. Our findings are consistent with the National Academy of Science (2009) accepted norms and expectations in the conduct of research within communities of practice.

Synthesis of results

This study's findings suggest that the care we envisage for ourselves helps to fashion the care we give to what is around us. Acknowledging who we are as people and the

relationship of our personal ethics to the care we give ourselves can assist us in enriching the ethical care we provide to the environment and the Earth. An interesting finding of this study is the suggestion by students that they need to monitor and evaluate their own ethical care as this accounts for their success or failure in providing care for what is around them. Studies have shown that self-care can be empowering and provide personal resources to care for others (Burkhardt & Nagai-Jacobson, 2001; Stark & Weinbaum, 2018). A continual assessment and awareness of one's level of care can be influential in indicating the need for greater care and lead to a determination as to what can be done (Pope & Vasquez, 2016) to mitigate the risk that our Earth faces.

It is the responsibility of geoscientists to pose questions in the face of climate change, pollution, and sustainability. Through this responsibility, the value of the Earth and other species could be recognized and appropriately valued. As described by Pang et al. (2003), the fundamental issue underlying the ethical responsibility to care lies in "what one ought to do" or "what one ought to be" (p. 305). Our findings suggest that the first step to becoming an ethical geoscientist lies in both what one ought to do and be. The students identified that for a geoscientist to be considered ethical, it is their responsibility to do ethical scientific work and be scientifically literate. There was a shared assumption among many of the students that when people know about the value of the Earth and what surrounds them, ethical care for the environment and society will follow.

We link competence of care to trust in the conduct of science. Trust is the cornerstone upon which the scientific enterprise is practiced. Society has faith that the findings of scientific study are an honest and accurate reflection of the effort of the researcher. Researchers have similar confidence in their colleagues' meticulous data collection, use of acceptable analytical and statistical methods, accuracy of findings reporting, and respect for the work of other researchers (National Academy of Science, 2009). Therefore, geoscientists should strive to be competent in their practice in order to ensure that the knowledge they construct is trustworthy, and that it contributes to a deeper environmental literacy within the public. The ultimate concern is with arising to care, to exert effort to repair and sustain our shared world.

Limitations

The study captured the perceptions of a small number of geoscience majors from a single geoscience course. Though the participant pool was diverse in terms of demographics, it is unclear how the results can be generalized to other geoscience courses and students. Furthermore, the use of structured reflection essays did not permit the further probing of students' perceptions of ethics that perhaps could have been achieved with interviews or focus groups. Finally, our interest was on the ethical thoughts that students developed from the explicit instruction of ethics in the course and not the measure of students' ethical learning progression. Hence, we did not consider the influence of the differences in the pre-and-post reflection periods would have made on students' reflections in our analysis.

Future work

The results and limitations identified in this study suggest the need for additional research on geoethics education. Students in our study identified important ethical knowledge and skills, but we do not yet know how they develop these knowledge and skills. Hence, future research should investigate how students develop ethical knowledge and skills during their education. Similarly, a study that investigates geoscience educators' conceptions of ethics and how they teach the construct to students is needed. To expand on our findings, future research should also use a broader participant pool and interviews and surveys to elicit students' knowledge in-depth. This future research could probe, for example, how ethical inquiry practices contribute to their understanding and practice of geoethics. We also suggest future research to use identical pre-and-post prompts so that students' ethical learning progress can be documented to identify the effectiveness of the instruction.

Implications for geoscience education

The results from this study suggest two main implications for geoscience education. First, students' ethical development can be fostered through critical reflections that explicitly focus on ethics. Providing opportunities for critical and ethical reflection during authentic geoscience experiences helps students to connect their personal and scholarly values to the public purposes of the geosciences. Instructional and learning strategies that emphasize critical and ethical "lenses" for reflection can foster this connectivity. However, this cannot be done in students' personal vacuum. It would be important to calibrate these personal reflections with (a) group discussions to see the degree to which there is convergence of attitudes toward these values, or perhaps alternate perceptions, or even disagreements—these can be productively explored in guided group discussions; and b) with any number of Codes of Conduct from American Geoscience Institute (AGI), GSA, AGU, etc., that would reinforce the students' inclinations toward ethical behaviors.

We also suggest that instructors create reflective instructional and assessment strategies, akin to the "approach through imagination" utilized by Kirkman (2021), to foster students' interest in environmental ethics. This instructional strategy uses students' moral imaginations to address ethical issues that develop in environmental and communal settings. In such a context, assessment is done through individual written reflections on a specific choice within the context of the larger issue.

The second implication of this study is concerned with ways of thinking about the purposes and practices of geoscience. With this ethics of care framing, our disciplines become our chosen tools for ethical living. In their essays, students

described a felt responsibility to society, humanity, the environment, and their disciplines. Within the course context, taking responsibility for these things demanded the competent practice of the discipline, its methods and its standards. Several students reported that a great deal of self-work was needed to accomplish this. As students strove to be caring people, they had to competently wield whatever tools they had at their disposal—whether those were geoscience knowledge and skills or moral values—in order to provide adequate care within their immediate setting. This is much different from seeing ethics as an appendage to our disciplines; rather, with a care framework, our disciplines—their theories and practices—become the instruments of our caring, the instruments we use to live the ethical lives we desire.

In close, we suggest that instructors use strategies that foster students' sense of care and interest in geology both as a science and ethical practice. We argue that when students are trained in this way, their ethical considerations will go a long way to promote sustainability and reduce anthropogenically-induced Earth hazards.

Conclusion

In this study, we set out to identify the ethical reflections of geoscience students as to what they think about ethics in geoscience practices and habits. We asked participants to individually reflect on what it means to be an ethical geoscientist. We collected and analyzed student reflections collected early in the semester before the first of two fieldtrips and later in the semester after the second field trip in a Sedimentology course. Student reflections revealed that an ethical geoscientist is someone who is attentive to their own care. The students believe that it is when we are able to care for our own self and actions that we can develop the capacity to shape our responses carefully and critically to care for society and the Earth.

Our results also revealed that an ethical geoscientist is one who takes responsibility to care for the needs of the society and Earth. Students shared in their reflections that it is an ethical responsibility for geoscientists to create a geoscience-literate society through effective knowledge sharing strategies and practices. When this is done, it will promote society's understanding of their responsibilities toward the environment and Earth. Finally, being an ethical geoscientist also involves a great deal of competence in providing care to society and the Earth. The students described that competency related to the accurate and precise collection of data and the iterative synthesis of information is important, because competence in these areas is required to provide ethical care to both society and the Earth. The ultimate concern is with arising to care—to exert effort to repair and sustain our shared world.

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