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Shaping geoethical geoscientists: awareness, relevance, and responsibility

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Abstract

Geoethics is an essential yet underdeveloped component of geoscience education in regions experiencing significant environmental and social impacts from resource extraction. Grounded in relational ethics, we investigate the extent to which students recognize the ethical, societal, and environmental dimensions of geoscience practice. Using a sequential explanatory mixed-methods design, we surveyed 193 undergraduate and graduate students across Ghanaian higher education institutions and conducted follow-up interviews with 11 students to interpret patterns of awareness, relevance, and responsibility. Findings indicate low but emerging awareness of geoethics, with over 54% of students intuitively engaging with ethical ideas despite limited formal instruction. More than 62% primarily conceptualized geoethics as a code of conduct, and 58.5% as moral principles. Interview data showed that students associated geoethics mainly with truthfulness, integrity, respect, and accountability, while also recognizing its relevance to decision-making, professional behavior, and environmental stewardship. Approximately 88% of students reported geoethics as relevant to geoscience research and practice, and 88.6% viewed it as relevant to academic work. Students strongly affirmed responsibility toward themselves, colleagues, society, and the natural environment, although their interpretations often emphasized rule-based compliance and reputation management rather than relational engagement with affected communities. In addition, more than 45% of students reported limited departmental support and insufficient curricular integration

of geoethics, leaving them underprepared for real-world ethical dilemmas. The study offers an empirical foundation for developing culturally relevant geoethics curricula that promote ethically grounded and socially responsive geoscience practice. The findings underscore the need to embed geoethics within coursework, field experiences, and research mentorship to cultivate geoscientists capable of addressing Ghana's environmental challenges with responsibility, transparency, and care.

Keywords: Geoethics, Higher education, Geoethical awareness, Geoethical responsibility, Relational ethics.

1. Introduction

The philosophical foundation of ethics holds that humans, the environment, and all non-human elements have intrinsic value and therefore deserve moral respect and protection (Rolston, 1988). This perspective challenges human-centred views that treat nature only as a resource, instead encouraging stewardship, sustainability, and ecological integrity toward the Earth system (Rolston, 1988; Peppoloni and Di Capua, 2017, 2021c). Emerging research in sustainability and environmental ethics underscores the need for Science, Technology, Engineering, and Mathematics (STEM), especially geoscience education to integrate geoethics, emphasizing responsible engagement with the Earth system and society (Bohle, 2021; Georgousis et al., 2021; Peppoloni and Di Capua, 2021b). Integrating geoethics is essential for preparing geoscientists who are not only technically competent but also ethically aware of their responsibilities to society and the Earth system (Peppoloni and Di Capua, 2017, 2021b; Nyarko et al., 2023; Fore et al., 2024).

Despite, growing recognition of the importance of geoethics in geoscience education, existing curricula often remain fragmented, narrowly focused, and insufficiently aligned with students' lived contexts and developmental readiness (Peppoloni and Di Capua, 2017, 2021b; Keane and Asher, 2021). For example, Peppoloni and Di Capua (2017) and Keane and Asher (2021) note that current geoethics instruction emphasize academic honesty and research integrity while neglecting broader concerns such as social responsibility, sustainability, and ethical responsiveness toward the environment and society. This means that geoethics education must

extend beyond factual knowledge, as ethical practice in geoscience involves more than knowing rules or definitions. It requires the ability to reason, reflect, and act responsibly in complex, real-world contexts (Di Capua et al., 2019; Keane and Asher, 2021; Nyarko et al., 2023). Accordingly, geoethics education should be deliberate, contextual, participatory, reflective, and proactive, supported by dedicated curricula and syllabi that foreground the ethical, social, and cultural dimensions of geoscience practice in higher education (Peppoloni and Di Capua, 2017, 2021b; Bohle and Di Capua, 2019; Keane and Asher, 2021; Fore et al., 2024).

In Ghana, unregulated resource extraction has polluted major rivers, destroyed farmlands and forest ecosystems, and significantly undermined sustainable development efforts (Musah, 2025). Given escalating environmental and social impacts, it is imperative to introduce geoethics education in Ghanaian curricula that embeds ethical, relational, and sustainability-oriented content to promote socially responsible and sustainable geoscience practice. Analyses of geoethics integration in formal curricula highlight its potential to foster ethical awareness of human-Earth system interactions, particularly in regions affected by environmentally or socially impactful extractive practices (Hellqvist, 2019; Nyarko et al., 2023; Vasconcelos et al., 2023; Villacorta et al., 2024). However, the lack of empirical research on how Ghanaian undergraduates understand and apply geoethical principles makes it challenging to design curricula aligned with their conceptual readiness and learning needs. Without these evidence-based insights, it is difficult to select contextual examples that connect geoethics to students' lived experiences, limiting the development of curricula that can meaningfully foster ethical awareness, responsibility, and sustainable geoscience practice in Ghana.

Thus, in this study, we apply relational ethics theory to assess how students perceive the relevance of geoethics in geoscience research and practice, and how they take responsibility for ethical decisions. We specifically answer the following research questions:

1) What level of ethical awareness do students demonstrate in relation to geoscience?
2) How do students conceptualize geoethics, and what ethical principles or values do they associate with geoscience?
3) (a) How do students perceive the relevance of geoethics to geoscience education and practice?
   (b) How do students understand their personal responsibility in addressing ethical challenges in geoscience?

This is an essential step for designing deliberate, contextual, participatory, reflective, and proactive curricula. From a relational ethics perspective, geoethical awareness extends beyond rule compliance to include attentiveness to how geoscientific actions affect people and the environment. Examining students' awareness through this lens

reveals how they value responsibility, respect, and interdependence in addressing Ghana's environmental and societal challenges, informing more context-sensitive and ethically grounded geoscience education. This approach helps prepare future geoscientists to advance technical knowledge while acting with awareness of their ethical and relational obligations to people, places, and the planet (Bohle and Di Capua, 2019; Peppoloni and Di Capua, 2021b).

2. Literature background

2.1. Geoscience, ethics and the Ghanaian context

The increasing demand for sustainable resource management and environmental protection has heightened the debate on the role of ethics in geoscience education and practice. In Ghana, this issue is particularly critical because of the country's reliance on mineral extraction, groundwater sources, and land-based livelihoods. Recent research (Sapah et al., 2024, 2025) has highlighted significant structural gaps in geoscience education, particularly the limited inclusion of sustainability principles, environmental ethics, and social considerations. These deficiencies reveal that traditional, purely technical training alone does not adequately prepare graduates to handle ethical dilemmas in natural resource management.

Worldwide, geoethics provides a normative and conceptual foundation for promoting responsible geoscience practices. Nagy and Bohle (2021) highlight that geoethics positions geoscientific expertise with a broader sense of responsibility to both society and the Earth system, going beyond technical skills to include moral responsibilities. Multiple contributions to Geoethics for the Future (Peppoloni and Di Capua, 2024) underscore these duties. Stewart (2024) promotes an ethics of "Earth stewardship", emphasizing human wellbeing, intergenerational justice, and sustainability. Likewise, Williams et al. (2024) contend that ethical geoscience practice necessitates community involvement, sensitivity to local priorities, and transparent communication. These principles are especially pertinent where extraction affects vulnerable communities. Herrington and Gordon (2024) further draw attention to the ethical challenges associated with mineral production, such as environmental damage, unfair distribution of benefit, and the lack of accountability to impacted communities.

These global perspectives are directly relevant to Ghana's geoscience sector, where ethical issues are prevalent. Concerns regarding social inequity and environmental degradation have been exacerbated by mining activities, unregulated groundwater exploitation, land-use conflicts, and poorly coordinated stakeholder engagement

(Adonteng-Kissi and Adonteng-Kissi, 2017; Arhin et al., 2018; Emmanuel et al., 2018). Despite the intricate ethical environment, geoscience programs in Ghana rarely include formal ethics training. Many educational institutions prioritize the development of technical skills, and provide limited opportunities for engagement with community dialogue, professional responsibility, and ethical decision-making (Mogk and Geissman, 2014; Appiah and Awuah, 2016; Sapah et al., 2024). This discrepancy between ethical issues and the preparation of students hinders efforts towards sustainable development and diminishes public trust in geoscience institutions.

Despite the longstanding advocacy by scholars such as Mogk et al. (2017) for the integration of ethics into geoscience curricula, Ghana has yet to implement comprehensive reforms in this area. Ethical principles fundamental to geoscience, encompassing transparency, ecological stewardship, fairness in resource allocation, and intergenerational responsibility, remain peripheral in most academic programs (Herrington and Gordon, 2024; Stewart, 2024; Williams et al., 2024). Considering the environmental challenges and socioeconomics linked to natural resource utilization in Ghana, incorporating geoethics into higher education is crucial for developing geoscientists who can act in the public's interest.

2.2. Status of ethics and ethics education in Ghana

Within Ghana's higher-education system, the importance of ethics education is increasingly acknowledged as critical for professional growth and national progress. Nevertheless, there remain considerable deficiencies in the way ethics is taught, understood, and incorporated within institutions. While universities prioritize the development of moral character, ongoing challenges such as corruption, academic dishonesty, inadequate policy enforcement, and inconsistencies within institutional culture hinder the advancement towards creating environments founded on integrity (Brimble and Stevenson-Clarke, 2005; Ampuni et al., 2019).

Discipline-specific literature supports this finding. Within the realm of accounting education, ethical considerations receive minimal pedagogical focus, resulting in graduates who are inadequately equipped to address ethical dilemmas in their professional practice (Onumah et al., 2012; Nsor-Ambala and Onumah, 2015). In the field of information sciences, the lack of structured training in information ethics courses leads to issues such as data misuse, plagiarism, and cybercrime (Dadzie, 2011). These findings indicate that ethical awareness, in isolation, is not enough without intentional curriculum development, practical training, and ongoing institutional commitment. The healthcare industry exemplifies the disparity between professional behaviour and ethical knowledge. As noted by Coleman (2023)

healthcare providers often have a theoretical understanding of ethical principles, yet their practical application is frequently inconsistent. This gap highlights the need for ongoing, practice-oriented ethics training that links theory to daily professional practice.

In a broader context, national discussions on ethics often emphasize public accountability, governance, transparency, and research integrity. Despite this increased discourse, ethics remains a secondary concern in many academic programs. Specifically, in the STEM disciplines, ethics education typically only covers the protocols of research ethics (Brock and Barry, 2012), which give students procedural guidance on lab conduct. However, it often inadequately prepares them for ethical dilemmas encountered in fieldwork or issues related to stakeholder engagement and environmental stewardship. There is a growing demand for more structured approaches to ethics education across disciplines. This demand spans from information ethics (Dadzie, 2011) to professional ethics in higher education (Riabova et al., 2023), as well as global efforts such as Globethics.net, which stress the importance of institutional responsibility in promoting ethical cultures.

These broader dynamics in question have a direct impact on geoscience education. While the global literature emphasizes the significance of geoethics, community engagement, and environmental responsibility (Mogk and Geissman, 2014; Azevedo, 2021; Peppoloni and Di Capua, 2021a; Jadhav, 2025), these subjects remain secondary in Ghanaian geoscience programs, which predominantly focus mainly on technical training and research ethics. Students have limited exposure to ethical reasoning frameworks that address the intricate moral issues related to land use, mineral extraction, groundwater management, and community relations. Therefore, improving ethics education in geoscience is both a national priority and an international necessity.

In summary, the literature indicates that although Ghana has made progress in recognizing the value of ethics education, much work remains to incorporate ethics meaningfully and consistently across various disciplines. A clear, discipline-specific system of ethics instruction aligned with institutional commitments, pedagogical methods, and professional expectations would greatly enhance the development of graduates capable of making ethically informed decisions and supporting sustainable national growth.

2.3. Major gaps in the literature

Geoethics is instrumental in the world today; nevertheless, the existing literature shows several gaps, which have guided the methodological framework of this study.

Although there have been wide discussions about teaching geoethics and the need for professional responsibility, little or no work has been done to investigate how geoscience students, especially those in Ghana and across Africa, understand, internalize, and use geoethical principles in their work. Research shows that ethics is not strongly embedded in the higher education system of Ghana, and many geoscience programs do not give meaningful attention to community engagement, sustainability or ethical decision-making. Nonetheless, no study has examined students' readiness or experiences with ethical dilemmas. Furthermore, earlier analyses often embrace a rule-driven or procedural lens on geoethics, consequently overlooking how students relate to the contextual, relational, and value-focused facets of relational ethics. This study was moulded by the highlighted flaws and aimed to probe students' perception, conceptualization, perceived importance, and accountability in relation to social and environmental topics. Therefore, it substantiates the application of a sequential explanatory mixed-methods approach, wherein quantitative data on awareness and accountability were supplemented by interviews that delved into students' relational reasoning, personal experiences, and interpretations of ethical practice within the socio-environmental milieu of Ghana.

3. Theoretical framework: relational ethics

> *One is drawn, then, to the ineluctable conclusion that moral values are specific to various cultures or subcultures in various times and specific places. Such a conclusion is no small matter because it reveals what may be viewed as the primary source of values: human relationships. Whether any activity is a good in itself – possessing intrinsic value – remains conjectural (Gergen, 2019, p. 16).*

Gergen (2019) emphasizes that ethical awareness is not merely about following a fixed code of conduct or applying universal principles but noticing how one's actions affect others and learning from those interactions. This perspective calls for a relational ethics framework because it shifts the focus from isolated decision-making to the quality and consequences of relationships (Bergum and Dossetor, 2005; Fore, 2022). At its core, relational ethics highlights aspects such as mutual respect, interdependence, dialogue, and responsibility toward others and the contexts in which individuals act. It involves attentiveness to how actions influence others and the networks of connection they are part of, making ethics a practice of care and responsiveness to the interconnected world (Tronto, 1998; Gergen, 2019; Nyarko et al., 2023). In the context of geoethics, this approach shifts the focus from adherence to abstract rules toward relational decision-making,

attending to the quality of relationships among geoscientists, communities, and the Earth system. Relational ethics enables geoscientists to navigate the complexity and diversity of real-world environmental and societal challenges, fostering responsibility, respect, and interdependence across social and ecological networks (Becker, 2012; Nyarko et al., 2023; Fore et al., 2024; Hess et al., 2024).

As Becker (2012) and Peppoloni and Di Capua (2017) emphasize, geoethics defines responsibility to the Earth system and society, and relational ethics deepens this perspective by treating the Earth not merely as a resource, but as a relational system of living and non-living entities that sustains human and ecological well-being. It also highlights how these relationships support or hinder meaningful co-construction. Relational ethics posits that knowledge emerges from relational processes, and engaging students as partners helps address power asymmetries inherent in co-construction (Gergen, 2011; Page, 2022). For example, in geoethical co-construction about the Earth, treating students as partners rather than subjects foregrounds the relational dimension (Peppoloni and Di Capua, 2017). This implies that, rather than conceptualizing and teaching geoethics as moral rules alone, students should be provided opportunities for relational dialogue, reflection, and collaborative ethical practice. By recognizing that responsible action emerges from ongoing interactions and interdependence, educators can better guide students' ethical awareness, encouraging reflection on how their choices shape, and are shaped by the social and ecological networks in which they participate (Nyarko et al., 2023; Fore et al., 2024).

Additionally, in geoscience, where ethical decisions are shaped by power, knowledge, culture, and the environment (Di Capua and Peppoloni, 2015; Peppoloni and Di Capua, 2023), relational ethics offers a valuable lens for geoethics. Both frameworks emphasize responsibility, respect, and interconnectedness not only between scientists and their work, but also among people, communities, and the Earth system as a whole (Bergum and Dossetor, 2005; Peppoloni and Di Capua, 2023).

In summary, relational ethics shifts the focus of geoethics from abstract codes of conduct to how students engage ethically in real-world interactions, offering a practical framework to explore their thought processes. In this study, we operationalized relational ethics as the framework guiding students' recognition and action on the ethical dimensions of geoscience practice in relation to people, society, and the Earth system. This operationalization offered an opportunity to design both surveys and qualitative coding focusing on students' awareness and conceptualization of geoethics, the relevance they attach to geoethics in practice, and their sense of responsibility to people and the environment.

4. Methods

4.1. Research design

The study follows the sequential explanatory mixed methods design illustration by (Ivankova et al., 2006). We first collected quantitative data using an adapted Students' Geoethical Reasoning Survey to find general patterns and levels of awareness in areas such as practical application, relevance and responsibility, and relational understanding. Based on these results, we then conducted qualitative interviews to explore the survey findings in more depth, asking students how they understand and apply geoethical principles in real-life situations. This approach helped us to connect the numbers from the survey with the stories and explanations from students, giving a fuller picture of both the measurable trends and the lived experiences behind them (Creswell and Plano Clark, 2018). For example, interview data were used to interpret discrepancies between students' reported awareness and merely having "heard of" ethical issues, to provide context for patterns related to perceived awareness, and to elaborate on how students framed geoethics. Furthermore, this design allowed us to understand what students know about geoethics, and how and why they act responsibly toward communities, the environment, and the Earth system.

4.2. Instrumentation

The Students' Geoethical Reasoning Survey (SGRS) was adapted from the measure of the geoscience community's awareness of the importance of the Geoethical Aspects of Geoscience Research and Practice (GAGRP) questionnaire (Peppoloni and Di Capua, 2020). The GAGRP questionnaire was adapted to explore students' awareness of the meaning and relevance of geoethics in geoscience research, practice, and academic activity, and their responsibility for geoethics.

In the first stage of the survey adaptation, the first and second authors read through the GAGRP and selected items we deemed relevant to student work (research, practice, and academics), our theoretical framework, and research goals. We selected 14 survey items from the general inquiry section to create an initial SGSR, designed to capture our operational definition of relational ethics by assessing students' awareness and understanding of geoethics, its relevance to practice, and their sense of responsibility toward people and the environment.

In the second stage, we modified the wording of the items for contextual relevance. We removed all words related to "professional or work activity" and replaced them with "academic activity" and "organization" with "academic department". For example,

the item "In how much of your research/professional activity do you consciously need to consider geoethics?" was reworded to "In how much of your academic activity (e.g., research, coursework) do you consciously need to consider geoethics?" and "How well do you feel supported by your organization and colleagues in ethical/behavioural matters?" was reworded as "How supportive are your department and colleagues in ethical matters?".

In the final stage of the SGRS survey, we sent it to geoscience and social science researchers (all Ghanaians) who are experts in geoconservation, geoheritage, and institutional ethics to review for content and construct validity, and cultural familiarity. Feedback from the experts was used to make appropriate corrections. For example, items assessing relevance and responsibility were measured using Likert-scale responses rather than the stand-alone format used in the GAGRP. Part A of the final SGSR survey (supplemental material) consists of six close-ended questions that ask students about their awareness of geoethics and definition, responsibility for geoethics, and support for geoethics, and two Likert Scale questions specifically related to the relevance of geoethics and importance of geoethical responsibility. The two-item scale measuring geoethics relevance demonstrated good internal consistency (Cronbach's $\alpha = 0.816$), as did the four-item scale measuring geoethical responsibility (Cronbach's $\alpha = 0.838$). Part B of the survey consists of five demographic questions about "gender, age, class level, hometown, and place of residence".

Interview questions were semi-structured and based on participant survey responses and theoretical framework. All participants were asked to expand on their geoethics definition, the relevance of geoethics to geoscience, their academic work and experiences, and environmental sustainability issues in Ghana and the role of geoethics in addressing them, and their geoethical responsibility to people and the environment.

4.3. Data sources

Institutional Review Board (IRB) approval for the study was obtained from Indiana University Human Subjects Institutional Review Board (IRB: #27999 What Do Geoscience Students Know About Geoethics? A Study of Ghanaian Student Geoscientists). Informed consent was also obtained from all participants prior to taking the survey. The Qualtrics SGRS survey link was shared through departmental email lists and in-class announcements with students in four public universities in Ghana that offer geoscience programs. A total of 217 responses were received, which were reduced to 193 after excluding participants who completed less than 80% of the questions. The survey participants were mostly male, aged 18-22, in level 400, from rural hometowns, and residing in urban areas (Table 1). The average

time for survey completion was 18 minutes. All responses were downloaded from Qualtrics in SPSS format and entered into IBM SPSS 29 software for data cleaning and analysis.

Following the initial analysis of survey responses by the first and second authors, a sub-sample of 20 students were invited to participate in a semi-structured interview, of which 11 agreed to take part. Interview participants were selected using purposive sampling from survey respondents who indicated willingness to participate in a follow-up interview. To ensure that the qualitative sample reflected a range of experiences rather than a single dominant perspective, our selection criteria included (1) representation across key demographic variables captured in the survey (e.g., academic level, institutional context) and (2) variation in survey responses related to the focal constructs of the study (i.e., awareness and conceptualization of geoethics, relevance, and responsibility). Interview data were used to contextualize, elaborate, and provide deeper insight into patterns observed in the quantitative results, particularly areas where survey responses suggested challenges, barriers, or variability in experiences. In some instances, qualitative findings also offered nuance or contrast to aggregate quantitative trends.

Most interview participants were male, aged 26-30, graduate students, from suburban hometowns, and residing in urban areas. None of the students aged

Demographic	Survey participants (N = 193)	Interview participants (n = 11)
Age (years, percentage)	18-22 = 126, 65.3% 23-25 = 38, 19.7% 26-30 = 9, 4.7% 31-40 = 15, 7.8% 41 or more = 5, 2.6%	18-22 = 4, 36.4% 23-25 = 2, 18.2% 26-30 = 3, 27.3% 31-40 = 2, 18.2%
Gender (number, %)	Male = 131, 67.9% Female = 62, 32.1%	Male = 6, 54.5% Female = 5, 45.5%
Class level (number, %)	Level 100 = 49, 25.4% Level 200 = 38, 19.7% Level 300 = 23, 11.9% Level 400 = 50, 25.9% Graduate = 33, 17.1%	Level 100 = 1, 9.1% Level 200 = 1, 9.1% Level 300 = 2, 18.2% Level 400 = 3, 27.3% Graduate = 4, 36.4%
Hometown (number, %)	Rural = 82, 42.9% Suburban = 81, 42.4% Urban = 28, 14.7%	Rural = 4, 36.4% Suburban = 5, 45.5% Urban = 2, 18.2%
Place of residence	Rural = 19, 9.9% Suburban = 45, 23.6% Urban = 127, 66.5%	Suburban = 3, 27.3% Urban = 9, 72.7%

Table 1. *Demographic information of survey and interview participants.*

41 or older, or those residing in rural areas, responded to the interview invitation. All interviews took about 20-65 minutes and were conducted by the third author via zoom and teams, except for one in-person and one zoom interview conducted by the first author. During the interviews, each participant's survey responses were available to the interviewer to allow for deeper probing. All interviews were audio and video recorded and transcribed verbatim into word document for analysis.

4.4. Data analysis

Quantitative analysis was conducted by the first and second authors. To identify students' conceptualization of geoethics, we conducted a frequency analysis of their responses to the items on the definition of geoethics, whether they had heard of geoethics, the relevance and consideration of geoethics, why geoscientists should behave ethically, and the important reference values for geoscientists. We further conducted a chi-square analysis of these items to identify demographic differences in response. For geoethical responsibility items, we conducted frequency, chi-square, independent samples t-tests, and one-way ANOVA analysis to identify differences in responses.

Chi-square was used to measure relationships between categorical variables, i.e., "yes" or "no" questions by comparing observed counts to expected counts. Practical significance was interpreted using Cramer's V. Independent sample t-test was used to compare means of independent variables that has exactly two groups, in this case gender. Statistical significance was measured using Cohen's d. Finally, ANOVA was used to measure and compare means across independent variables with three or more groups (i.e., age, class level, hometown, and place of residence). Because the data included multiple groups with unequal sample sizes, we controlled potential Type I errors using Bonferroni post hoc adjustments to reduce the likelihood of false positives when comparing group differences. We maintained a significance level of $\alpha = 0.05$ and applied Bonferroni post hoc adjustments in the ANOVA analyses. P-value was used to measure statistical significance for all ANOVA analysis.

For the purposes of this study, effect sizes were interpreted as practically meaningful only when accompanied by statistical significance and of at least a small-to-moderate magnitude. Non-significant results, regardless of effect size, were interpreted cautiously, reflecting limited practical impact. Additionally, for "select all that apply" question, response categories were not mutually exclusive. Thus, each selected option was treated as a separate binary variable, and reported frequencies and percentages reflect the number of respondents selecting each item rather than summing to 100%.

Qualitative analysis followed thematic analysis (Creswell and Plano Clark, 2018). The third and fourth authors independently reviewed the eleven interview transcripts, identified and highlighted potential codable passage(s), and conducted open coding to generate a list of preliminary codes. The two authors then discussed and merged their codes into an initial coding scheme. Using this initial coding scheme, the first author independently coded all transcripts and identified three additional codes. These new codes were discussed and integrated into the coding scheme, followed by axial coding to organize the codes into broader themes. A final discussion was held to refine and define the themes and codes, resulting in a final coding scheme consisting of 3 categories, 8 themes and 13 codes (Table 2). The third author then applied the final coding scheme to the transcripts and compiled representative quotes in NVIVO 15.

To validate the codebook and ensure reliability, we engaged in intercoder reliability. The third author randomly selected five interviews with highlighted passages and

Themes	Code and example of student quote
Conceptualization of geoethics	
Geoethics as ethical and moral principles: describes moral values and principles that guide geoscientists in making responsible and just decisions about the Earth and its resources, emphasizing truthfulness, honesty, integrity, and respect for both people and the planet in all geoscientific activities.	**Truthfulness:** *geoethics is the act of being truthful. If your data is not right, you can have ways and means to still communicate what you want to communicate without making people think it is the right thing or it is not. You just have to tell the truth.* **Integrity:** *it simply means integrity. Your integrity must play the first rule. You have to be fair in everything. You have to be honest. You shouldn't practice fraud in everything you do. So, I think that's the reason why I chose it.* **Respect:** *to me, geoethics means acknowledging people when we work with them. As a graduate student, if there's an undergraduate student who is helping you, it is ethically right that you acknowledge the impact and that is respect.*
Geoethics as a decision-making framework: evaluating human actions that shapes how one thinks about actions and responsibilities in any geoscientific context.	*So geoethics, to me, is that principle that guides you in knowing right from wrong, and how to conduct yourself in any geoscientific study.*
Geoethics as adherence to professional standards: refers to the professional and legal standards and values that guide responsible behavior in geoscience research and practice.	**Following formally established laws and guidelines:** *geoethics concept in this case to me relates to the behavior and regulations that we need to follow in our work any regulations governing geology.*
Geoethics as environmental stewardship: emphasizes management and protection of the environment for the future.	**Management and protection of the environment:** *appreciate the essence of everything in our environment and not destroying them. For example, the rocks that are at the field sites if it is not there for the upcoming students to also go and visit and see, it means the practical aspects of their studies would be missing, and that means we did not protect the environment for them.*

Themes	Code and example of student quote
	Relevance of geoethics
Professional reputation and trustworthiness: captures the idea that ethical behaviour in geoscience is linked to earning trust, credibility, and respect within the professional community.	**Reputation:** *we had some data I was working on and when financial challenges prevented me from running it [analysis] again, we had no choice but to stop but I continued using it anyway because the scarcity of data left me with limited options. Although no one knows it, I question my reputation as a scientist every day.* **Trustworthiness:** *in some situations, the temptation to adjust or 'massage' the results to gain approval is very high. However, that would be unethical and lose the peoples' trust in the long run.*
	Ethical responsibility
Environmental accountability: refers to the responsibility geoscientists have to *respect, protect, and care for the environment* in their work. Emphasizes that safeguarding the environment is not optional but a personal and professional duty.	**Environmental Accountability:** *And the other aspect is what I learned in school is that we must respect and protect the environment and so it is my responsibility to be geoethical toward the environment. Geoethics helps us to protect the environment.*
Responsibility towards self, others, and society: involves recognizing that geoscientists' work affects diverse communities and therefore requires acting ethically and promoting responsible behaviour among colleagues such as carrying a duty to intervene or report concerns to ensure ethical conduct is upheld.	**Collective responsibility:** *I think geoscientists should work ethically in every environment because the kind of work we do interacts with different people of different walks of life.* **Encourage right behaviour:** *yes, it's highly necessary that we tell or look over colleagues' shoulders to ensure they do the right thing.* **Responsibility to society:** *we are a society or an organization and so whatever we do will have an impact on the society or organization. So, I think it is right to be ethical and speak with people to also be ethical or if something goes wrong, it is our ethical duty to speak with somebody who's higher up, who has some level of authority over them to intervene.*
Responsibility in research and practice: captures transparent, honest, accurate, respectful conduct and reporting of research, including the safe and legal collection of data, the presentation of all results regardless of significance, and the avoidance of any manipulation that could misrepresent findings.	**Responsible research conduct:** *in research work, when I go to pick data or whatever information that I need to pick, am I sure that I'm picking the right kind of data or I'm just trying to do something to represent something? Because at the end of the day, the data will have to speak so that I don't compromise on what I have to do.* **Transparency in research report:** *I think it's very important that we are ethically responsible and transparent in communicating our research findings. False interpretation can lead to wrong investment and that's a loss to everybody.*

Table 2. *Themes, codes, and example of quotes from student interviews.*

coded them independently. The first and fourth authors then independently coded the same five interviews and compared their codes. We then calculated the intercoder reliability between the three authors by dividing the number of agreements by the total number of coded passages. We reached an average intercoder agreement of 92.57%, indicating that our codebook is highly reliable.

5. Results

The following symbols are used to represent their respective statistical terms: $\bar{x}$ = mean score, s.d. = standard deviation, SE = standard error, p = statistical significance value at 95% confidence interval, F = statistic ratio, and η^2 = Eta-squared point estimate (for ANOVA tests), V = Cramer's (for chi-square tests), and d = Cohen's (for t-tests).

5.1. Students' geoethical awareness

A total of 193 respondents (Table 3) responded to the question on whether they were aware of ethics applied to geoscience, namely geoethics. Of these, 105 (54.4%) indicated "Yes," while 88 (45.6%) indicated "No." Although most students who were aware of geoethics were 18-22 years old, male, in level 100, from suburban hometown, or lived in urban areas, this pattern was not statistically significant. Similarly, most students who reported being unaware of geoethics were 18-22 years, in level 400, came from or lived in urban areas, with no significant differences. Additionally, the small effect sizes, V, reported for each of the groups suggests minimal practical impact of demographics on students' geoethics awareness.
Student interviews reflected a low but emerging level of ethical awareness. Dela recognized that she had encountered geoethical ideas before but did not realize these concepts were part of a broader ethical framework:

> *I haven't heard about geoethics directly, though I have come across some of its concepts in conversations. At the time, I wasn't fully aware that what I was hearing was related to geoethics.*

Similarly, Haruna emphasized that:

> *Even though it is not specifically stated as, this is geoethics and this is what you do that is ethically sound, they still push the same concepts in class. For example, if you go to the field, the first thing you are told to do is sample ethically.*

Variable	N	Population	Yes (n = 105), %	No (n = 88), %	χ^2	df	p	Cramer's V
Age vs. Geoethics Awareness	193	18-22	61.0%	70.5%	4.158	4	.385	.147
		23-25	21.0%	18.2%				
		26-30	6.7%	2.3%				
		31-40	7.6%	8.0%				
		41-more	3.8%	1.1%				
Gender vs. Geoethics Awareness	193	Male	70.5%	64.8%	.714	1	.398	.061
		Female	29.5%	35.2%				
Class level vs. Geoethics Awareness	193	100	26.7%	23.9%	5.958	4	.202	.176
		200	22.9%	15.9%				
		300	10.5%	13.6%				
		400	20.0%	33.0%				
		Graduate	20.0%	13.6%				
Hometown vs. Geoethics Awareness	193	Rural	41.9%	43.2%	1.484	2	.476	.088
		Suburban	45.7%	37.5%				
		Urban	12.4%	17.0%				
Place of residence Geoethics Awareness	193	Rural	11.4%	8.0%	1.232	2	.540	.080
		Suburban	21.0%	26.1%				
		Urban	67.6%	63.6%				

Table 3. *Student awareness of geoethics and demographic differences.*

Ama described the need to actively *promote geoethical awareness* rather than relying on brief or incidental mentions in class:

> *I think it would be right for them [teachers], to introduce something like the concept of geoethics that you actually teach the people, and not passive statements they make in class.*

5.2. Conceptualization of geoethics

Students most often viewed geoethics as a set of moral and ethical principles that guide judgments of right and wrong in geoscience. The most selected definition was "Guidance towards the right and wrong of humans' choices" (58.5%), followed by "Identifying values on which to base right and wrong" (50.8%). Students who selected these definitions were mostly 18-22 years old, male, from suburban hometowns, or living in urban areas, with Level 100 and Level 400 students most frequently

Variable		Moral and ethical Principles			Decision-making and ethical reflection		Professional and behavioural standards		Stewardship
		Guidance towards the right and wrong (n = 113, 58.5%)	Identifying values to base right and wrong (n = 98, 50.8%)	Moral principle (n = 1, 0.5%)	Exploring Issues around human choices N = 48, 24.9%)	Confront ethical dilemmas (n = 29, 15%)	Defining codes of conduct or behaviour (n = 120, 62.2%)	Establish Legal constraints to human behaviour (n = 57, 29.5%)	Stewardship (n = 1, 0.5%)
Age	18-22	68 (60.18%)	61 (62.24%)		29 (60.42%)	17 (58.62%)	75 (62.5%)	30 (52.63%)	
	23-25	24 (21.24%)	19 (19.39%)		11 (22.92%)	5 (17.24%)	24 (20%)	15 (26.32%)	1 (100%)
	26-30	5 (4.42%)	4 (4.08%)				6 (5%)	1 (1.75%)	
	31-40	11 (9.73%)	10 (10.20%)		5 (10.42%)	5 (17.24%)	11 (9.17%)	9 (15.79%)	
	41 or more	5 (4.42%)	4 (4.08%)	1 (100%)	3 (6.25%)	2 (6.90%)	4 (3.33%)	2 (3.51%)	
Gender	Male	79 (69.91%)	70 (71.43%)	1 (100%)	36 (81.25%)	23 (79.31%)	87 (72.5%)	40 (70.18%)	1 (100%)
	Female	34 (30.09%)	28 (28.57%)		12 (25%)	6 (20.69%)	33 (27.5%)	17 (29.82%)	
Level	100	27 (23.89%)	21 (21.43%)		15 (31.25%)	7 (24.14%)	28 (23.33%)	13 (22.81%)	
	200	25 (22.12%)	22 (22.45%)	1 (100%)	7 (14.58%)	4 (13.80%)	26 (21.67%)	8 (14.04%)	1 (100%)
	300	11 (9.73%)	7 (7.14%)		4 (8.33%)	3 (10.34%)	12 (10%)	5 (8.77%)	
	400	27 (23.89%)	25 (25.51%)		9 (18.75%)	7 (24.14%)	31 (25.83%)	16 (28.07%)	
	Graduate	23 (20.35%)	23 (23.47%)	1 (100%)	13 (27.08%)	8 (27.59%)	23 (19.17%)	15 (26.32%)	
Hometown	Rural	43 (38.05%)	41 (41.84%)		16 (33.33%)	8 (27.59%)	52 (43.33%)	20 (35.09%)	1 (100%)
	Suburban	52 (46.02%)	44 (44.90%)		21 (43.75%)	14 (48.28%)	52 (43.33%)	28 (49.12%	
	Urban	18 (15.93%)	13 (13.27%)	1 (100%)	11 (22.92%)	7 (24.14%)	16 (13.33%)	9 (15.79%)	
Residence	Rural	10 (8.85%)	8 (8.16%)		10 (20.83%)	3 (10.34%)	9 (7.5%)	6 (10.53%)	
	Suburban	24 (21.24%)	25 ((25.51%)	1 (100%)	12 (25%)	7 (24.14%)	32 (26.67%)	16 (28.07%)	
	Urban	79 (69.91%)	65 (69.39%)		26 (54.17%)	19 (65.52%)	79 (65.83%)	35 (61.40%)	1 (100%)

Table 4. *Distribution of students' demographics and response to definition of geoethics.*

represented. One student also described geoethics simply as dealing with moral principles.

When asked in interviews to explain why they view geoethics as moral and ethical principles, most participants emphasized truthfulness, specifically referring to the

accurate representation of data and findings. For example, Ama and Nii drew attention to being truthful irrespective of the consequences:

> *It means being truthful about your hypothesis or your expectations. Are you reporting your findings without hiding important information that may go against your objectives or are you half-baking? I mean projecting half-truths in your research.* – Ama.
> *[Geoethics] That's the belief system that I have to always speak the truth, no matter how, small or how big it is or how it affects me.* – Nii.

Other conceptual emphasis of geoethics included integrity, specifically referring to being guided by strong moral values/behavior, and the commitment to doing geoscientific work correctly and rejecting dishonest practices, such as misreporting results or giving unearned credit in all aspects of research and collaboration. Comments included:

> *I think that it is important that we do whatever we do, we do it right. You don't have to input values that you did not practically collect, or pretending like that testing or research or lab work never existed.* – Enyonam.
> *It means being honest when we see something. In our work, I saw something bad about adding people's names when they were not there. If I didn't see it, that's fine. But I saw it. I can't corroborate the lie, so I had to cancel it. I must cancel the person's name from the list because he's obviously not here.* – Jimmy.

Students further emphasized respect, the ethical principle of giving proper credit for others' work and recognizing that acknowledging contributions and avoiding exclusion are essential to maintaining respect within the geoscientific community. Rhoda shared that:

> *For me, it means whatever I'm doing, what are the ethical values that I have to incorporate into my behavior and research. For example, in terms of academic work for example if I use somebody's material I know consciously even though you might want to call it plagiarism, but I mean, morally, I think once somebody has done it and you are making use of that person's work in your work, it behaves on me to acknowledge that person.*

And Kojo shared:

> *It means respecting people in the research process. Whatever we do, research, academics, anything that we do, people help us. So, it is ethically great [right]*

to acknowledge all the help. It also shouldn't be that they are sidelined because maybe they are younger, or they don't know what's up."

A second set of responses framed geoethics as a reflective and decision-making concept, such as "Exploring issues around human choices" (48, 24.9%) and "Confronting ethical dilemmas" (29, 15%). No student aged 26-30 years selected these options. Students from suburban hometowns and those living in urban areas were more likely to choose these definitions.

In interviews, students described geoethics as a guiding framework that helps individuals distinguish ethical from unethical behavior in geoscience practice. Derek shared that:

So geoethics is that principle that guides you in your decision making as to what is right and what is acceptable in any geoscientific study. It generally refers to what we do, deciding what is wrong or bad.

And Kira shared:

Geoethics refers to the rules or the right and wrong that are applied to geology or the application of geoscience.

A third conceptualization of geoethics emphasized formal guidance for professional behavior, such as codes, norms, and legal frameworks. Most students (62.2%) selected "Defining codes of conduct/behavior," primarily aged 18-22, male, in Level 400, from rural or suburban hometowns, or living in urban areas. Additionally, 29.5% defined geoethics as "Establishing legal constraints to human behavior."

In the interviews, students elaborated that geoethics involves following both external (formal rules and regulations) and internal (personal or intrinsic moral sense) established laws and guidelines. Dela described that following these guidelines ensure that actions align with accepted professional and ethical norms in geoscience:

I understand geoethics as the practice of following the appropriate laws and guidelines, whether they are formally provided or intrinsic. In this sense, geoethics means abiding by these standards to guide our actions responsibly.

Haruna emphasized the role of geoethics as a framework to regulate research in the absence of standards:

I view geoethics to mean standards that we must follow as geoscientists, but as I mentioned, we don't really have a body that I know of now that regulates

our research, so geoethics is what guides the work that we do to make sure we are following the right thing.

Finally, one student, Ricky (pseudonym), a male graduate student between 23-25 years, from an urban hometown and residing in a suburban area described geoethics as "environmental stewardship." In an interview, he explained that ethical geoscience involves minimizing harm to both ecosystems and communities, highlighting that caring for the environment is a central ethical responsibility:

Safety is key, so that's why I chose the environmental aspect. I think geoethics is a commitment to safeguard both environmental integrity and humans through safety practices.

Students expressed similar views in the interviews, emphasizing that geoscientists have an ethical responsibility to both the environment and affected communities, and a duty to protect Earth systems for current and future generations:

Geoethics means that humans need to strive to have the best possible impacts on the environment, which is probably a more direct interaction we have, as well as on the people living in the environment and the people affected by the environments where we work. – Derek

Similarly, Kira emphasized that:

Geoscientific activities produce the best possible outcomes for the environment.

5.3. Relevance of geoethics in geoscience

In response to the relevance of geoethics for geoscience research and practice, 11.9% (23) of students indicated it is irrelevant, 46.1% (89) indicated it is relevant, and 42.0% (81) considered it extremely relevant. An independent-samples t-test comparing gender showed a statistically significant difference. Male students ($\bar{x} = 4.18$, $SD = 1.01$) rated geoethics as more relevant than female students ($\bar{x} = 3.87$, $SD = 1.29$), $t(191) = 1.68$, $p = .048$. The effect size was small (Cohen's $d = 0.28$), suggesting that while the difference is statistically significant, the practical impact is modest. A one-way ANOVA showed a significant difference in the relevance of geoethics across class levels, $F(4, 188) = 3.83$, $p = .014$, with a small effect size ($\eta^2 = .064$), indicating limited practical impact. Level 400 students ($\bar{x} = 4.36$, $SD = 0.72$) reported higher

relevance than other class groups, but Bonferroni post hoc tests showed that the significant difference was only between Level 400 and Level 300 students ($\bar{x} = 3.39$, $SD = 1.59$, $p = .005$). No statistically significant differences were found by age group, $F(4, 188) = 0.48$, $p = .750$, $\eta^2 = .010$; hometown, $F(2, 188) = 0.81$, $p = .445$, $\eta^2 = .009$; or place of residence, $F(2, 188) = 0.31$, $p = .735$, $\eta^2 = .003$. Although students aged 26-30, those from rural hometowns, and those living in urban areas reported slightly higher relevance scores, the small effect sizes indicate that these demographic factors had minimal practical influence on perceptions of geoethics relevance.

Regarding the relevance of geoethics in academic activities, 10.1% (19) of students indicated it is irrelevant, 25.9% (49) indicated it is relevant, and 62.7% (121) indicated it is extremely relevant. Although female students ($\bar{x} = 3.80$, $SD = 1.08$) rated geoethics as slightly more relevant than male students ($\bar{x} = 3.74$, $SD = 1.07$), this difference was not statistically significant, $t(191) = 0.37$, $p = .716$, with a very small effect size ($d = 0.06$), suggesting that the observed trends may have minimal practical impact.

Furthermore, students aged 26-30, those in level 400, those from rural hometowns and those residing in suburban areas scored highest for the relevance of geoethics in academic activities. However, ANOVA showed no significant pairwise differences in the relevance of geoethics in academic activities and age, $F(4, 188) = .772$, $p = .545$, $\eta^2 = .016$; class level, $F(4, 184) = 1.186$, $p = .318$, $\eta^2 = .025$; hometown, $F(2, 188) = .001$, $p = .999$, $\eta^2 = .000$; or place of residence, $F(2, 188) = .752$, $p = .473$, $\eta^2 = .008$. The small effect sizes, η^2, for all the groups suggest minimal practical impact on perceptions of geoethics relevance.

In the interviews, students described the relevance of geoethics to geoscientists as being connected to trustworthiness. In their view, trustworthiness comes from consistently following ethical principles, which makes others confident in their honesty and integrity. Kojo shared that:

> *If we fail to uphold ethical standards, we risk losing the trust and confidence of others. The worst outcome is to work tirelessly and then have your competence or results doubted.*

Similarly, Ricky underscored that:

> *Well, to me, geoethics is very important because it frames a way of life. It defines who and what a geoscientist is, and how they should behave and act. For example, ensuring that projects are not assigned in ways that cause harm. If we don't carry out our work ethically and responsibly, who would trust us with more work.*

Aseweh and Kira noted that maintaining ethical conduct builds a positive reputation, while violating the ethos leads to loss of respect and professional standing:

> *It [been unethical] would affect my reputation in the long run, and I'll lose my credibility in front of people I want to win trust from people to have a sustainable career in academia and research.* – Aseweh.
> *I realize how important ethics is because there were times when I received results from several laboratories, and one that I worked with extensively. Their managers insisted I accept the results as they were, without questioning. But when I tried to interpret the data, it created significant problems for me, even affecting my mental well-being, which continues to this day. Since then, I started questioning the professional standing of the managers and the researchers over there.* – Kira.

Students also considered geoethics not just as scientific guidance for truth and reputation, but as a framework for professional behavior that supports teamwork and a positive work environment. For example, Enyonam emphasized the role of geoethics in developing effective collaboration at the workplace:

> *And with geoethics it can help me in my career, because when let's say I get a job in a company and then I work under a supervisor, with geoethics, it can help me develop a good relationship with my supervisor and the people there in the company.*

Overall, students viewed geoethics as highly relevant to both geoscience research and academic activities, with most rating it as relevant or extremely relevant. While small but statistically significant differences emerged by gender and class level, particularly higher ratings among male and Level 400 students, effect sizes were consistently small, indicating limited practical impact. The interviews reinforced the survey findings by showing that students view geoethics as central to trust, professional identity, collaboration, and sustains long-term credibility in geoscience, underscoring geoethics as both a professional and relational foundation of geoscience practice.

5.4. Responsibility for geoethics

The majority of students (174, 90.2%) indicated that their activities have an impact on society, while 19 (9.8%) indicated "no". Among those who indicated "yes", most were male (67.2%), aged 18-22 (64.9%), in level 400 (27.6%), from rural hometowns (44.5%), or residing in urban areas (67.6%). Similarly, most students (169, 87.6%) indicated

that their activities affect the natural environment, while 11.4% (22) indicated no. Of those who indicated "yes", the majority were male (67.5%), aged 18-22 (66.3%), in level 400 (27.2%), from suburban hometowns (41.7%), or residing in urban areas (65.5%).

5.4.1. Responsibility toward self, colleagues, society and the environment

Most students (106, 54.9%) rated their individual geoethical responsibility in geoscience as "very important". More than a quarter (52, 26.9) rated it as "extremely important", while 7.3% (14) rated it as "moderately important", 9.8% (19) as "slightly important" and 1% (2) as "not at all important". Independent-samples t-tests showed no significant gender differences in perceived geoethical responsibility toward self, ($t(191) = 0.33$, $p = .371$, $d = .952$), colleagues, ($t(191) = 0.06$, $p = .952$, $d = .902$), society, ($t(191) = 0.11$, $p = .912$, $d = 1.045$) or the natural environment, ($t(191) = 0.54$, $p = .592$, $d = 1.064$). Although the associated effect sizes were large by conventional benchmarks, the absence of statistical significance suggests that these estimates are unstable and should not be interpreted as practically meaningful gender differences. ANOVA results did not show any statistical pairwise difference in the importance of individual geoethics responsibility and age ($F(4, 188) = 1.521$, $p = .198$, $\eta^2 = .031$), class level, ($F(4, 188) = 2.053$, $p = .089$, $\eta^2 = .042$), hometown, ($F(2, 188) = 1278$, $p = .281$, $\eta^2 = .013$), or place of residence, ($F(2, 188) = .304$, $p = .738$, $\eta^2 = .003$). However, students aged 26-30, those level 200, those from urban hometowns, and those living in suburban areas reported the highest importance for individual geoethical responsibility. The consistent small effect sizes suggest these demographic factors have minimal impact on students' perceived geoethical responsibility towards self. In the interview, Nii emphasized that being ethically responsible to oneself means holding a high standard of accountability which allows for personal ownership and pride in what one creates:

> *I think it is important to be ethical to myself because in everything I do, I must take accountability. So, in my work, I must do it responsibly and professionally, so that when someone takes my work, the person can see the accuracy in it. Even if not for the accuracy, you can stand up for your work.*

Derek suggested that being ethically responsible to oneself includes taking the time to understand the rules and your own responsibilities, and by doing so, you put yourself in a position to participate meaningfully:

> *I think if you are aware of the rules and your responsibilities, it plays a critical role in a team because you are able to contribute.*

More than half of the students (100, 51.8%) rated their geoethical responsibility toward colleagues as "very important" while 21.8% (42) rated it as "extremely important". About 16.6% (32) rated it as "moderately important", 8.8% (17) as "slightly important" and 1.0% (2) as "not at all important". ANOVA showed no significant differences in geoethical responsibility toward colleagues by age, $F(4, 188) = 1.506$, $p = .202$, $\eta^2 = .031$; class level, $F(4, 188) = 1.550$, $p = .189$, $\eta^2 = .032$; hometown, $F(2, 188) = 1.379$, $p = .254$, $\eta^2 = .014$; or place of residence, $F(2, 188) = .034$, $p = .966$, $\eta^2 = .000$. The consistently small effect sizes indicate that these demographic factors have little influence on students' perceived geoethical responsibility toward colleagues.

In interviews, students described that geoscience research is not done in isolation, thus, behaving ethically toward colleagues is an important responsibility:

> *I believe geoscientists must act ethically because we don't work in isolation. Our work connects with institutions, departments, and courses, and it carries real consequences. Acting responsibly helps ensure the world becomes a better place.* – Ama
>
> *I think geoscientists should work ethically in every environment because the kind of work we do interacts with different people of different walks of life.* – Ricky

Haruna and Jimmy emphasized geoethical responsibility toward colleagues as a guide for ethical behavior:

> *I do believe it is my ethical responsibility to let my colleagues and people know first about ethics, and you approach them with a lot of respect, because sometimes you might not know what you don't know. You must also confront them and encourage them to do the right thing.* – Haruna.
>
> *Sometimes people have to be told what is expected of them, what is needed of them. You cannot just assume that everybody knows. So yes, it's highly necessary and my responsibility that they behave ethically.* – Jimmy.

Most students, 51.3% (99) also rated geoethical responsibility toward society as "very important, while 23.8% (46) rated it as "extremely important", 13.5% (26) as "moderately important", and 5.7% (11) each as "slightly important", and "not at all important". While ANOVA results showed significant differences in geoethical responsibility toward society by age, $F(4, 188) = 3.654$, $p = .007$, $\eta^2 = .072$, Bonferroni post hoc tests revealed that the difference was only between students aged 26-30 ($\bar{x} = 4.78$, $SD = .44$) and those aged 23-25 ($\bar{x} = 3.47$, $SD = 1.12$, $p = .007$). There were no significant differences by class level, $F(4, 188) = 1.887$, $p = .114$,

$\eta^2 = .039$; hometown, $F(2, 188) = .940$, $p = .392$, $\eta^2 = .010$; or place of residence, $F(2, 188) = 1.947$, $p = .146$, $\eta^2 = .020$, with very small effect sizes suggesting minimal practical influence.

Students described in interviews that responsibility for ethics in society is important because society looks up to them as researchers to do the right thing. Rhoda emphasized that:

> *It is my responsibility to be ethical in my community when it comes to my research. In all times you must consider geoethics because rules apply to everything and if you don't apply any rules it can lead to any consequences, and the consequences might be bad for our society.*

Enyonam highlighted that ethical geoscience practice involves respecting the communities where work takes place in other to build trust:

> *Let's say you go to a community to map, you would have to consult the chiefs and elders there, and ask them for permission, or tell them why you are here, why you are exploring their town. It shows some kind of respect and trust.*

Finally, most students (94, 48.7%) rated geoethical responsibility toward the natural environment "very important", 28% (54) as "extremely important, 11.4% (22) as "moderately important", 6.7% (13) as "slightly important", and 5.2% (10) as "not at all important". Although ANOVA indicated significant differences by age, $F(4, 188) = 2.700$, $p = .032$, $\eta^2 = .054$, Bonferroni post hoc tests revealed no significant pairwise differences. There were no significant differences by class level $F(4, 188) = 2.160$, $p = .075$, $\eta^2 = .044$; hometown, $F(2, 188) = .872$, $p = .420$, $\eta^2 = .009$; or place of residence, $F(2, 188) = .861$, $p = .425$, $\eta^2 = .009$. The consistently small effect sizes indicate that these demographic factors had minimal practical influence on perceptions of geoethics responsibility toward the environment.

Interview data showed that students mostly held ethical responsibility towards environmental accountability. Ama shared that:

> *We are taught that in any small way, we should be aiding things that distract our environment, water bodies, and the next generation. So, I believe I am responsible for protecting the environment.*

And Jimmy also shared that:

> *Making sure that wherever we are working, they are upholding standards that will protect the environment.*

Students overwhelmingly recognized the importance of geoethical responsibility across all domains (i.e., toward self, colleagues, society, and the environment). Most rated personal responsibility as "very" or "extremely" important, highlighting a strong commitment to ethical conduct in their work. Statistical analyses revealed few meaningful differences by gender, age, class level, hometown, and place of residence generally had minimal impact, with consistently small effect sizes. Interview data reinforced the perceptions that acting ethically toward oneself enables ownership and pride in one's work, while ethical behavior toward colleagues fosters teamwork and guides others toward responsible practice. Similarly, students framed geoethical responsibility toward society and the environment as essential for maintaining public trust, respecting communities, and protecting natural systems, demonstrating an integrated understanding of geoethics as both a personal and collective obligation in geoscience.

5.4.2. Responsibility in research and practice

The students strongly associated geoethics responsibility in research and practice (Table 5) with individual virtues such as honesty (64.8%), accountability in research (57.5%), and professional courtesy toward others (55.4%). Fewer students indicated obligations that extend beyond the self, such as protecting the environment (38.3%), complying with regulations (34.2%), assuring societal benefits (26.9%), or "doing a good job" for broader stakeholders (24.4%).

Variable	N = 193 (n, %)
Honesty in all aspects	125 (64.8%)
Accountability in conducting my research	111 (57.5%)
Professional courtesy and fairness in working with others	107 (55.4%)
Being compliant with laws and regulations	66 (34.2)
Assuring societal benefits	52 (26.9%)
Providing environmental protection	74 (38.3)
Doing a good job	47 (24.4)
Other: implementing safety protocols	1 (0.5)

Table 5. *Distribution of students perceived geoethical values in research and practice.*

In the interviews, students highlighted a developing sense of geoethical responsibility that extends beyond data collection to transparent, reciprocal communication with

affected communities. Students emphasize the need to explain what researchers are doing and why their work matters, signaling an understanding that ethical research involves more than obtaining permission but making research legible and meaningful to the people whose lives and environments are involved. Both Dela and Nii underscored this sentiment, respectively:

> *So, it is ethical for us to more or less like explain to them what we do and also the impact of what we do on their daily lives. Why is it necessary to do what we do?* – Dela.
> *It's ethical for you to tell the people what you are doing, what's the essence of what you're doing.* – Nii.

Overall, students most strongly associated geoethical responsibility with personal integrity and professional conduct, particularly honesty, accountability, and fairness in working with others. Fewer students emphasized external obligations such as legal compliance, societal benefits, and environmental protection, suggesting that geoethics is primarily understood as an individual and interpersonal responsibility rather than a broader relational accountability.

5.5. Support and challenges with ethical matters

Most students rated their department and colleagues as slightly supportive of ethical matters (45.8%, 88), followed by very supportive (33.9%, 65) and not supportive (20.3%, 39). Male students ($\bar{x} = 2.15$, $SD = 0.70$) rated support slightly higher than female students ($\bar{x} = 2.11$, $SD = 0.78$), but this difference was not statistically significant, $t(191) = 0.26$, $p = .796$, $d = 0.73$. Although the effect size is moderate to large, indicating a noticeable difference in perceived support between male and female students, the lack of statistical significance means this difference should be taken cautiously.

ANOVA results showed a significant difference by class level, $F(4, 187) = 2.96$, $p = .021$, $\eta^2 = .059$. Bonferroni post hoc tests indicated significant differences between Level 100 ($\bar{x} = 2.24$, $SD = 0.66$) and Level 300 students ($\bar{x} = 1.70$, $SD = 0.82$, $p = .026$), and between Level 300 and graduate students ($\bar{x} = 2.30$, $SD = 0.68$, $p = .019$). No significant differences were found by age, $F(4, 187) = 1.23$, $p = .298$, $\eta^2 = .026$; hometown, $F(2, 187) = 1.62$, $p = .200$, $\eta^2 = .017$; or place of residence, $F(2, 187) = 0.83$, $p = .440$, $\eta^2 = .009$.

In interviews, students expressed that their programs are not providing sufficient emphasis on ethics and prioritizing ethics education, which leaves them underprepared

for the ethical challenges they face. Kira emphasized that:

> *I don't think the department is doing enough, because it's not like something they are really teaching, or it's like a course they are providing. This makes it hard when I am faced with any ethical problem.*

And Ricky also shared that dealing with ethical matters is a national issue as there is little to no institutional structure to support, monitor, or enforce ethical practices:

> *We don't have any organizational body to ensure ethical behavior except maybe the police. So even on campus people act however they want and conduct research in any way they like. I really appreciate that you are doing this study ethically by showing us the approval, reading the consent form, and helping us understand the research.*

Students perceived departmental and collegial support for ethical matters is modest rather than strong, with nearly half rating it as only slightly supportive. Perceptions of support did not differ meaningfully by gender, age, hometown, or place of residence, but did vary by class level. In particular, Level 300 students reported significantly lower support compared to both Level 100 and graduate students, suggesting that perceptions of ethical support may decline mid-program before improving at more advanced stages. These findings point to the need for more explicit ethics instruction such as including geoethics in courses and field protocols or clearer institutional structures to support ethical practice.

6. Interpretation and discussion

There have been calls for geoethics education for decades, yet awareness of geoethics appears low across the student population, and no particular group stands out as being substantially more informed than others. The lack of significant associations suggests that gaps in geoethical understanding are structural rather than demographic, reflecting an educational environment where exposure to geoethics is limited for all students. Even students nearing graduation and presumed to have the most geoscience training show limited awareness. Their reflection shows that while geoethical principles may be present in their educational or social environment, they are not clearly named or systematically integrated into higher education curricula in a way that supports deeper understanding. This indicates an important gap in explicit instruction: students may be intuitively engaging with

ethical issues, but without clear framing, they cannot fully develop or apply geoethical reasoning.

The relatively high proportion of unaware students in more advanced levels suggests that students may progress through their programs without ever encountering formal instruction in geoethical principles. Similarly, the urban-rural patterns, although not statistically significant, suggest disparities in prior exposure and differences in how communities frame geoscience and its societal dimensions. In this sense, students' argument for integrating geoethics as a visible, explicit part of geoscience education should be taken seriously to help them develop a deeper, more informed understanding of their ethical responsibilities. This reflects an awareness that meaningful ethical learning requires deliberate engagement, discussion, examples, and context and not just scattered remarks.

Students primarily conceptualize geoethics in moral and value-oriented terms, emphasizing honesty, accountability, fairness in professional practice, and care within human and environmental relationships. While this moral foundation is essential, such understandings reflect an emerging orientation of Ghanaian geoscience students toward relational ethics (Bergum and Dossetor, 2005; Peppoloni and Di Capua, 2017). However, results also suggest that many students rely heavily on rule-based understandings of geoethics, defining it primarily through codes of conduct, standards, and legal constraints rather than through reflective or relational perspectives. Although a subset of students viewed geoethics as involving human choices and ethical dilemmas, this was not the dominant view, indicating that reflective dimensions of geoethics are not yet widely internalized (Peppoloni and Di Capua, 2012; Mogk, 2017). This rule-centered framing, while important for establishing accountability can limit the development of relational ethics, which requires engagement with context, values, and the lived experiences of affected communities (Frodeman, 2015; Peppoloni and Di Capua, 2017; Fore, 2022), and risks reducing ethics to compliance rather than cultivating moral reflection, empathy, and shared responsibility (Peppoloni and Di Capua, 2021b).

The patterns observed in students' views of geoethics reveal a generally strong recognition of its importance, yet the nuances across gender, class level, and interview responses point to deeper issues in how relevance is understood and applied. The clear majority who regard geoethics as relevant or extremely essential suggests that students see ethical practice as integral to geoscience, aligning with broader arguments that modern geoscience requires not only technical competence but also moral and social responsibility (Peppoloni and Di Capua, 2012; Mogk, 2017; Nyarko et al., 2023). However, the significant gender difference though small in effect size indicates that male students may view geoethics through a more instrumental or professional lens, whereas female students' non-significant but higher valuation

of geoethics in academic contexts may reflect a relational orientation toward ethics, consistent with research showing gendered patterns in ethical sensitivity and communal reasoning (Gilligan, 1982; Jain and Kansal, 2025). Additionally, the elevated relevance scores among Level 400 students suggest that exposure to advanced coursework, field experiences, or research responsibilities may heighten students' awareness of ethical dimensions. This pattern echoes findings that ethical understanding deepens when learners encounter concrete situations requiring judgment, uncertainty management, and responsibility (Cronin et al., 2021).

Students' belief that ethical behavior preserves reputation while violations erode respect highlights how geoethics is being internalized as reputation management rather than a framework for navigating complex societal and environmental relationships. Such a perspective, while not incorrect, reveals a gap between students' understanding and the broader goals of geoethics, which requires engaging with diverse values, negotiating ethical tensions, and cultivating trustworthy relationships not only within the profession but also with the public and the environments geoscientists study (Frodeman, 2015; Peppoloni and Di Capua, 2017). Although the focus on maintaining credibility within the professional community shows that the students understand ethics as a social process, their reflections suggest that this sociality is limited to reputation management rather than mutual care, reciprocity, or shared responsibility.

Furthermore, relational ethics privileges responsiveness over dogmatic following of rules and situates responsibility within ongoing social and ecological ties (Bergum and Dossetor, 2005; Frodeman, 2015). Thus, the students' emphasis on responsibility toward colleagues, society, and the environment indicates a foundational orientation compatible with relational ethics. This aligns with core geoethics principles of respect, openness, and accountability, showing that students view ethical practice as a relational duty: researchers must not only act responsibly but also ensure that communities understand the purpose and potential impacts of geoscience activities. Such reflections suggest an emerging awareness that ethical responsibility is built through dialogue, shared understanding, and recognition of the community as a partner rather than a passive subject of research.

However, most of the students' emphasis of geoethics in research and practice primarily as personal conduct and the relatively low emphasis on societal and environmental responsibilities indicates a gap in how students conceptualize these relationships. A relational ethics posits that geoethical practice is about sustaining reciprocal, long-term relationships with people, places, and ecosystems, and underscores the need for care, reciprocity, and shared accountability in geoscience decision-making (Becker, 2012; Peppoloni and Di Capua, 2017). Additionally, institutional context matters. Perceived limited departmental support and gaps

in formal education weaken students' capacity to enact relational responsibilities. When departments give only limited support, students miss out on mentors, clear expectations, and opportunities to practice handling ethical situations. This erodes students' sense of responsibility toward their colleagues, and they tend to focus on simply following rules rather than thinking ethically.

6.1. Contributions beyond existing geoethics education research

This study makes three key contributions to the geoethics education literature. First, it provides an empirical baseline from Ghana, a context that has been largely absent from prior geoethics research, thereby extending understanding beyond the Global North and highlighting structural gaps in geoethics education within geoscience programs in Ghana. Second, the findings offer a relational-ethics interpretation of student framing, showing that while students strongly value ethics, they often understand geoethics primarily in terms of reputation management, rule compliance, and professional credibility rather than engagement with communities, care for environments, or shared responsibility. This distinction advances prior work by demonstrating how students' ethical reasoning is shaped by institutional context and limited instructional support, and by identifying an opportunity for geoethics education to move beyond compliance-based models toward relational, dialogic, and socially embedded ethical practice. Third, through mixed-methods triangulation, the study integrates survey data with student interviews to show not only low levels of formal geoethics awareness, but also how students nonetheless engage intuitively with ethical ideas. This combination reveals a disconnect between implicit ethical sensibilities and explicit curricular framing that would not be evident from quantitative or qualitative data alone.

7. Implications for geoethics education

Geoethics aims to foster responsible interaction between geoscientists, society, and the Earth system. However, when students equate the relevance of geoethics primarily with adherence to codes to maintain reputation, the deeper relational and contextual dimensions risk being overshadowed. These findings therefore point to the need for pedagogical approaches that move beyond rule-based compliance and help students appreciate geoethics as a framework for engaging with communities, negotiating values, and making informed, responsible decisions in complex settings. Such measures shift ethics from an individual checklist to a distributed practice embedded in everyday research activities and professional formation. Strengthening

relational geoethics requires institutional commitments such as curricular integration of case-based learning, supervised field experiences that foreground community engagement, mentorship that models reciprocal accountability, and spaces for collective reflection on harm and trade-offs (Mogk, 2017; Cronin, 2021). Additionally, experimental or case-based instructional interventions could be designed and tested to evaluate how specific pedagogical strategies such as community-engaged field experiences, scenario-based simulations, or relational ethics dialogues shape students' ethical reasoning, relational awareness, and professional identity (Mogk, 2017; Fore et al., 2024).

We suggest the following implementation practices:

- Within coursework, geoethics can be incorporated through case-based learning embedded in existing classes (e.g., field methods or research design), where students analyze real or locally relevant scenarios involving community impacts, uncertainty, and ethical trade-offs (Mogk, 2017; Peppoloni and Di Capua, 2017; Nyarko et al., 2023). These cases can be assessed through reflective writing, group discussions, or ethical decision-making exercises that require students to justify actions in context rather than simply identify rules (Fore et al., 2024).
- Supervised field experiences can be integrated into fieldwork to foreground ethical engagement with communities by requiring students to consider consent, communication with local stakeholders, environmental disturbance, and power relations as part of field preparation and post-field reflection (Frodeman, 2015; Cronin et al., 2021). Assessment could include field journals or debrief sessions that explicitly ask students to reflect on ethical tensions encountered and how they were addressed.
- Mentoring and advising programs can model relational geoethics by making ethical reasoning visible in research supervision, collaboration norms, and departmental expectations (Peppoloni and Di Capua, 2021b; Hess et al., 2024). Creating regular spaces such as seminars, capstone courses, or reflective workshops for collective discussion of ethical dilemmas, harm, and trade-offs can further support students in developing a relational understanding of geoethics as a shared professional responsibility (Fore et al., 2024).
- Systematic evaluation of implementation practices through instructional interventions. Experimental, quasi-experimental or pilot implementations such as community-engaged field modules, scenario-based simulations, or facilitated relational ethics dialogues can be assessed for their effects on students' ethical reasoning, relational awareness, and professional identity development (Mogk, 2017; Cronin et al., 2021; Fore et al., 2024). Such evaluations would contribute to evidence-based geoethics education while strengthening the integration of relational ethics into geoscience training.

8. Limitations and future research

Although this study provides important insights into Ghanaian geoscience students' awareness and perceptions of geoethics, several limitations should be acknowledged. First, the sample while drawn from multiple public higher education institutions was limited to students who responded voluntarily to the survey and interview invitations. This self-selection may have resulted in overrepresentation of students who are more motivated, academically engaged, or already interested in ethics-related issues, potentially inflating the apparent levels of awareness or perceived responsibility (Creswell and Plano Clark, 2018). Second, although the sequential explanatory design allowed for deeper interpretation of quantitative patterns, the qualitative sample (n = 11) was relatively small and demographically narrow, as older students and those residing in rural areas did not participate. This limited the diversity of perspectives represented in the interviews and may have constrained the depth of cultural, social, or experiential nuance captured. Third, the adapted survey instrument, while reviewed for contextual validity, has not been validated extensively within African or Global South educational contexts, which may influence the reliability of some constructs.

Furthermore, geoethics awareness was measured through self-reported understanding rather than demonstrated ethical reasoning or decision-making. As a result, the study captures students' perceived familiarity and valuation of geoethics but cannot assess how effectively they would apply ethical reasoning in real or simulated geoscience contexts. Responses may also be influenced by social desirability bias, particularly given the moral nature of ethical topics. Students may have overstated their ethical awareness, responsibility, or adherence to ethical principles to align with perceived academic or professional expectations. Finally, while the mixed-methods design allowed for triangulation between survey and interview data, the qualitative findings reflect students' articulated reflections rather than observed behavior (Creswell and Plano Clark, 2018).

Future research should address these limitations by expanding sampling to include a broader range of institutions, including private universities, technical colleges, and geoscience training centers, to capture varied curricular approaches and social contexts. Longitudinal studies would also be valuable in examining how geoethical awareness develops across students' academic progression and into early career experiences, particularly as students move from classroom-based learning to fieldwork, internships, and industry placements. Comparative cross-national studies could further illuminate how contextual factors such as regulatory structures, community expectations, or histories of environmental harm shape students' geoethical perspectives and responsibilities.

Additionally, given that students often framed geoethics in rule-based rather than relational terms, future work should explore how cultural, institutional, and societal value systems influence ethical orientations in geoscience education across Ghana and other African contexts (Becker, 2012; Gergen, 2019). Future research should investigate faculty perspectives and institutional structures, as understanding the preparedness, beliefs, and constraints of educators is essential for developing a coherent and culturally grounded geoethics curriculum that supports sustainable and socially responsive geoscience practice (Peppoloni and Di Capua, 2017, 2021). Furthermore, future research could strengthen these insights by incorporating scenario-based assessments, fieldwork observations, or performance-based tasks to evaluate how students enact geoethical reasoning in practice.

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