BAMS Article

Shifting the Paradigm

Cultivating Socially Responsible Atmospheric Scientists through Leadership and Action

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KEYWORDS:
Education;
Societal impacts;
Social science

ABSTRACT: The geosciences have the lowest racial and ethnic diversity of all STEM fields at all levels of higher education, and atmospheric science is emblematic of this discrepancy. Despite a growing awareness of the problem, Black, Indigenous, people of color, persons with disabilities, women, and LGBTQIA+ persons continue to be largely absent in academic programs and in the geoscience workforce. There is a desire and need for new approaches, new entry points, and higher levels of engagement to foster a diverse community of researchers, scholars, and practitioners in atmospheric science. One challenge among many is that diversity, equity, and inclusion efforts are often siloed from many aspects of the scientific process, technical training, and scientific community. We have worked toward bridging this gap through the development of a new atmospheric science course designed to break down traditional barriers for entry into diversity, equity, and inclusion engagement by graduate students, so they emerge better prepared to address issues of participation, representation, and inclusion. This article provides an overview of our new course, focused on social responsibility in atmospheric science. This course was piloted during Fall 2021 with the primary objective to educate and empower graduate students to be "diversity champions" in our field. We describe 1) the rationale for a course of this nature within a graduate program, 2) course design and content, 3) service-learning projects, 4) impact of the course on students, and 5) scalability to other atmospheric science graduate programs.

https://doi.org/10.1175/BAMS-D-22-0077.1
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Supplemental material: https://doi.org/10.1175/BAMS-D-22-0077.2
In final form 11 May 2023

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The geosciences have the lowest racial and ethnic diversity of all science, technology, engineering, and mathematics (STEM) disciplines at all levels of higher education, and atmospheric science is emblematic of this discrepancy (NSF 2019). Despite a growing awareness of the problem, Black, Indigenous, people of color, persons with disabilities, women, and LGBTQIA+ persons continue to be largely absent in academic programs and in the geoscience workforce. Bernard and Cooperdock (2018) highlight that in the past 40 years, the number of granted PhDs in geosciences has remained flat and there has been "no progress on diversity." Diversity and inclusion initiatives will not be enough if all geoscience community members cannot achieve a sense of belonging (Dutt 2019; Puritty et al. 2017). In addition, diversity and inclusion efforts without strategic actions and measurable goals will not be effective in dismantling systemic racism and bias (Morris 2021). Further, abundant research indicates that the negative effects of global change will fall most heavily upon those underrepresented in the geosciences (Pörtner et al. 2022). This situation suggests that the training and research most needed to mitigate and adapt to global change excludes a substantial population, limiting valuable contributions these populations offer to the geoscience workforce.

New approaches, new entry points, and higher levels of engagement are needed to foster a diverse community of researchers, scholars, and practitioners in the geosciences. There have been several widely read opinion and commentary articles, over the last few years, that reinforce the community needs and challenges to do the necessary work to make the geosciences diverse, equitable, and inclusive (Burt et al. 2022; Ormand et al. 2022; Morris 2021; Morales et al. 2021; Harris et al. 2021; Quardokus Fisher et al. 2019). One challenge, among many, is that diversity, equity, inclusion, accessibility, and justice (DEIAJ) initiatives are often siloed from many aspects of the scientific process, training in geoscience curriculum, aspects of professional development for faculty and researchers, and portions of the geoscience scientific community. The development and implementation of our course represents our attempt to center DEIAJ principles in scientific research, education, mentorship, training, and professional development as part of our graduate education process. In the context of coursework, it highlights the importance of intentionally building these valued skills.

Here we describe the course design and content, student experiences, and learning from the course. We then conclude with strategies for departmental adoption in the broader geoscience community.

Course design and content.

Course overview. ATS 660 Social Responsibility in Atmospheric Science was piloted in Fall 2021 with an enrollment of 12 graduate students. In Fall 2022, 13 graduate students enrolled. Typical graduate course enrollments for elective courses enroll 5–8 students. The course is designed to provide students an opportunity to expand their personal and professional growth through readings, video lectures, guest speakers, and other activities to gain a critical understanding of intersectionality, gender, social identity, systems of oppression,

and historical perspectives on social change movements. Students engage with a diversity of scholarship to develop a robust understanding of foundational concepts and practices for personal and social change and to incorporate and disseminate these concepts through their science. The course content is designed to enable students to 1) identify how social identity (race, gender, sexuality, ability) shapes scientific thought and practice; 2) evaluate and explain the impacts (positive and negative) of science and technology on marginalized groups; 3) identify and respond to manifestations of implicit and explicit bias in STEM; 4) recognize social justice issues in the geoscience community and beyond and be able to design and implement interventions to affect change; and 5) act as advocates and allies for people with different life experiences than their own.

Instructional approach. The course embodies inclusive and intersectional teaching practices to ensure that all students thrive and that the broad range of diversity (e.g., race, national origin, abilities) within the class enriches learning (Lawrie et al. 2017). This approach attends to social identities and positionalities and seeks to change the ways systemic inequities shape dynamics in teaching–learning spaces, affect individuals' experiences of those spaces, and influence course and curriculum design (Iturbe-LaGrave 2020a,b; CRLT 2020). Instructors and students co-created expectations of one another during the first week of the course using activities described in Brookfield and Preskill (2012). We took time to allow everyone to share what they need to authentically participate, what they feel are the most important topics for discussion, and their goals for the course. Based on this activity, we established ground rules and provided students with examples of both listening and speaking ground rules from Caldwell and Frame (2016). We revisited "our expectations" continually over the semester for accountability.

Course content. During the first week of the course, we invited ImprovScience (https://improvscience.org/) to design and lead a 2-h session where the entire class (i.e., students and instructors) engaged in improvisational exercises and discussion. This program uses improv theater techniques to break down traditional barriers and build meaningful connections in groups and teams and demonstrates the value of diverse voices in teamwork and leadership. One example of an outstanding module led by ImprovScience included an exercise in saying "yes, and" in response to intentionally outlandish and sometimes off-the-wall ideas from the team. This exercise taught all participants that even if the idea was bold and hard to imagine as a success, by saying "yes, and" to the person and contributing helpful ways to make the idea successful, team dynamics and comradery were quickly built among the class. This and other group activities quickly broke down social barriers between participants, demonstrated the value of diverse voices in leadership, and enabled engaging and honest conversations about hard topics in the discussions that followed this program. We used many of the techniques from that first class to maintain a safe and inclusive learning environment throughout the semester. Throughout the duration of the course, students read a wide variety of high-impact publications and listened to several podcasts related to each module topic. We used a specific discussion framework [i.e., pyramid discussions (Brainfeed Magazine 2022) with focused questions] to ensure a robust and inclusive conversation of each set of readings (and podcasts). The remaining modules (as shown in Fig. 1) covered the following material: social identity, bias in STEM, gender and racial equity, intersectionality, critical race theory, sexual and gender harassment, cognitive and physical disability as it applies to the geosciences, stereotype threat and imposter experience, inclusion and belonging, allyship, and science communication. New readings and activities were added after the pilot year based on feedback from student participants. One example of new content was the inclusion of an interactive module called WAGES (Workshop Activity for Gender Equity Simulation),

Week	Topic	Readings/Activities	Week	Topic	Readings/Activities
Week 1	Introductions, motivations, expectation setting	Exercise: What is the class environment we want? How will we engage during challenging conversations?	Week 9	Gender harassment and discrimination	Fischer et al. 2021; Mattheis et al. 2022
Week 2	The Big Picture and Social Identity	Social Identity Wheel; Powell 2018; Bernard and Cooperdock 2018	Week 10	Access, Cognitive and Physical Diversity	Atchison et al. 2019; Kingsbury et al. 2020
Week 3	Bias in STEM	Implicit Association Test Dutt et al. 2016; Moss-Racusin et al. 2012	Week 11	Stereotype threat and imposter syndrome	Steele 2010; Tulshyan and Burey 2021
Week 4	Community Action Service-Learning Project Planning		Week 12	Inclusion and belonging	Harris et al. 2021; Cooperdock et al. 2021
Week 5	Gender equity and intersectionality	Ranganathan et al. 2021; Clancy et al. 2017; Mattheis et al. 2019	Week 13	Committing to Action: Fostering Allies and Accomplices in the Geosciences	Podcast: Brené Brown and Aiko Bethea: Creating Transformative Cultures; Affinity Arts Consulting
Week 6	Racial equity and critical race theory	Dutt 2019	Week 14	Science Communication and Social Justice	Johnson and Wilkinson 2020
Week 7	Cultural Diversity: A Global and International Perspective	Dowey et al. 2021	Week 15	Community Action Service-Learning Project Planning	
Week 8	Gender harassment and discrimination	Shields et al. 2011	Week 16	Community Action Service-Learning Project Presentations	

Fig. 1. Example of week to week syllabus. Course syllabus can be found at https://www.atmos.colostate.edu/gradprog/courses.php.

an experiential learning activity designed to educate individuals about the sources and cumulative effects of unconscious bias that underlie the development of inequity in the workplace, and that good intentions alone cannot prevent (Cundiff et al. 2014; Zawadzki et al. 2014, 2012; Shields et al. 2011). At the end of the course students work either individually or in small teams to develop a community action service-learning project that is their final deliverable of the course. The weekly syllabus, which includes the weekly topic, interactive activities, and readings, is provided in Fig. 1.

Examples of service-learning projects and community engagement

Consistent with many graduate courses in our department, students complete a final project. Based on course content and discussions, students worked in small teams to develop a community action service-learning project. Select examples of projects from Fall 2021 and Fall 2022 are provided in Fig. 2.

Student experiences. Using a mixed-method approach of surveys and interviews, the course was evaluated and reviewed by the Colorado State University (CSU) STEM Center (an external and independent evaluation) to better understand the student learning process and help course instructors improve course content and delivery.

Fall 2021 cohort. For the Fall 2021 cohort, the CSU STEM Center conducted a pre- and post-course online survey (via Qualtrics) and follow-up interviews. The survey tool used both open-ended qualitative and semantic differential quantitative questions to assess student learning outcomes related to the specific course objectives of fostering DEIAJ knowledge, DEIAJ promoting practices, and long-term DEIAJ behaviors (see Table S1 in the online supplemental material). It also asked about previous experience with DEIAJ activities, and 73% (n = 11) of respondents indicated that they had previously engaged with DEIAJ courses, events, or opportunities.

Project Description	Impact(s)
A Fall 2021 student participant drafted a departmental Code of Conduct following ADVANCEGeo guidelines. The code was presented at a faculty meeting early in the spring 2022 semester.	Over the Spring 2022 semester, the draft Code of Conduct was edited by the department and officially adopted by the faculty at the start of the Fall 2022 semester. Codes of conduct are important for reducing bias and discrimination in STEM (Willis et al. 2020).
Two Fall 2021 students reported on the lack of gender diversity in named student awards. At this point in time, all departmental awards were named after men.	Students established a committee (composed of students, research scientists, and faculty) to rename the Alumni Award in honor of the first woman to earn a PhD in the Department. This step makes the departmental awards more inclusive because women are more likely to win awards that are not named after men (Gibney 2022).
A Fall 2021 student participant redesigned a problem set associated with a required core course (Atmospheric Chemistry) to teach the concept of "chemistry lifetimes" while also exposing students to disparities in pollution exposure at schools (Cheeseman et al. 2022).	Graduate students are introduced to concepts of Environmental Justice early in their career at CSU so they can understand their potential roles as change agents (Lasker et al. 2017).
A Fall 2021 student surveyed graduate students about first generation identity, family education, and academic challenges. She then held a lunch and learn session presenting survey results and highlighted recent literature on first generation student experiences (e.g., Gardner 2013; Wofford et al. 2021; Gardner and Holley 2011).	The department is considering 1) how to best collect this information (among other metrics of diversity) to better uncover and remedy differential outcomes for graduate students, and 2) how to mirror other campus programs that offer support for undergraduate first-generation students and make first generation faculty more visible.
A Fall 2022 student opened a dialogue about diverse language and knowledge systems in science.	Participants learn to challenge the commonly held assumption that all important information is in English, understand the repercussions of science conducted primarily in English (e.g., Hunter et al. 2021), and see the barriers to global science (Amano et al. 2016).
A Fall 2022 student collected and summarized common language challenges among peers whose first language is not English.	Department is considering a language-focused buddy system to support scientific communication needs for all students. English language learners are considered underrepresented in STEM, but most effort is focused on K-12 education.
Two Fall 2022 students facilitated a workshop to raise awareness of biases in datasets and how they can influence research, particularly in machine learning models.	Workshop included graduate students, postdocs, and research staff from the Cooperative Institute for Research in the Atmosphere (CIRA) and the NSF AI Institute for Research on Trustworthy AI in Weather, Climate, and Coastal Oceanography (AI2ES). Understanding bias is needed to ensure climate applications of AI are ethical (Coeckelbergh 2021).

Fig. 2. Sample student project descriptions and their direct departmental impact(s).

The qualitative questions of the survey centered on students' definitions of core course concepts such as social identity and privilege, their perceived equity promoting practices, and long-term equity intentions and behaviors. We analyzed these questions by summarizing

the general themes that appeared, focusing on how the content of the responses changed. Figure 3 highlights two examples of qualitative responses and how they changed. The first example is of a concept definition, with the responses indicating that while the student entered the class with a notable basic understanding, they also exhibited a level of growth and complexity to their definitions in the post survey with added nuance and application-based insights. This is a pattern seen in many of the responses to questions about concept definitions. In the second example, we also observed changes in students' perceptions of their equity promoting practices, suggesting that students gained an understanding of ways they could put their knowledge into action, as well as a deeper understanding of the ways inequity and bias show up in atmospheric science. Overall, the qualitative data from this survey suggests that students entered into the course with a basic level of understanding and experience, potentially an indication of self-selection bias into the course, but nevertheless gained valuable insights and application based knowledge.

The quantitative questions in the survey asked students to rank their levels of comfort and confidence in identifying and addressing bias, as well as their interest in pursuing DEIAJ now or in the future. We analyzed these data using descriptive statistics and the exact sign test (Gibbons and Chakraborti 2010) of 11 paired pre–post responses. The exact sign test indicated that the medians of the paired pre–post differences were statistically significantly different than zero for a few questions: students' level of comfort identifying their own biases toward other people, races/ethnicities, and/or cultures ($p = 0.031$); level of confidence in identifying examples of bias in their life and/or workplace ($p = 0.016$); and level of comfort advocating for those experiencing bias ($p = 0.016$). This means that the null hypothesis of no change between pre-/post-tests was rejected, and further, based on the number of positive changes (i.e., higher post scores than pre), there is some support that students experienced increases in their respective levels of comfort and confidence in these domains (see Table S2 for full results). Nonetheless, these conclusions should not be interpreted to apply outside this context given the small sample size and the internally derived (i.e., nonpsychometrically tested) nature of the questions. Rather the purpose was to provide data to 1) inform how the course should develop and 2) understand potential impact.

Pre-Post student definition of "Social Identity"			
Pre	The identities that influence how you move through the world.	Post	How one chooses to identify or is perceived to identify based on visible and invisible characteristics. These characteristics situate the person within different social systems and, often, within hierarchies of oppression.
Pre-Post student answer to the equity practice question What skills do you feel like you have to respond to and address bias when you see it?			
Pre	I feel like I'm comfortable advocating for others but not sure how best to do so. I am good at listening and willing to bring forward the opinions of others and promote their needs. I understand the university institutional structure and support venues which makes it easier to find the right resources to help people.	Post	Thanks to this course, I have more concrete examples of how bias impacts the field of atmospheric science in particular. A willingness to listen and engage even when I don't know everything (don't have to know the absolute perfect response). Historical awareness that can help me recognize bias incidents more quickly.

Fig. 3. Examples of Fall 2021 cohort qualitative response pre–post changes.

Follow-up interviews were also conducted to gain a deeper understanding of students' experiences in the course, particularly around their perceived gains and the role of the course structure on their learning. While only 3 of the 12 students were available or agreed to participate, overall, they found the course interesting and valuable and emphasized the importance of its role in providing tangible, grounding knowledge around concepts that often feel difficult to articulate. Students also valued the contributions of guest speakers and the general structure of the class with its emphasis on discussion and connecting clearly to the readings. Finally, they felt empowered to begin engaging with DEIAJ where they were in their understanding and experience and did not have to do it "perfectly"—it became less of a daunting task than they previously thought. The main constructive critique of the course was that at times some materials and/or topics were repetitive, and they wished content adapted to knowledge they already had.

Fall 2022 cohort. Based on these initial promising findings about the impact of the course on improving students' knowledge, attitudes, and engagement around DEIAJ in atmospheric science, the evaluation shifted tactics for the Fall 2022 cohort. We utilized a baseline survey to guide the development of the course to reflect the incoming students experience and knowledge (i.e., a formative assessment tool) as a reflection of the likelihood of self-selection bias into the course as well as the expressed student interest in such adjustments. The baseline survey showed that students' knowledge and experience entering the course was similar to the Fall 2021 cohort—84.6% of respondents (n = 13) indicated previously engaging with DEIAJ courses, events, or opportunities before the course and their definitions of core concepts were similar in their level of detail and understanding. We also asked about their motivations to take the course, and students' responses centered around wanting to deepen their understanding of DEIAJ, leverage their lived experiences, and develop skills for how to address it in their work and lives. This information was used to gain insights on baseline knowledge of course participants and to determine the appropriate focal areas for course content.

To understand the impact of the course in a more robust way we utilized a retrospective post survey, adapting the validated scales found in Gurin et al. (2013) to assess the overall construct of intergroup collaboration and action. For example, the "self-directed action" scale started with a stem of:

> People can take a variety of actions to address issues of prejudice, discrimination, and injustices. Listed below are different actions. Indicate how confident you felt about your abilities in each of the actions BEFORE participating in the course and how confident you feel now AFTER participating in the course.

This stem was then followed by a number of items for students to rank their confidence, such as "Recognize and challenge the biases that affect my own thinking." We used a retrospective post format versus the pre-test/post-test design to reflect logistical needs as well as the documented benefits of improved accuracy of retrospective designs (Drennan and Hyde 2008; Howard et al. 1979). We selected the specific scales within the intergroup collaboration and action construct of self-directed action, other-directed action, intergroup collaboration, and post-college involvement as the most relevant to the course (Table A.5 in Gurin et al. 2013), omitting some items within these subscales that were not relevant to the course. We also utilized the pedagogy related scales of content, structured interactions, and intergroup dialogue facilitator effectiveness (Table A.7 in Gurin et al. 2013).

For the intergroup collaboration and action subscales, a comparison of the distribution of how students scored the items before and after participating in the course suggests

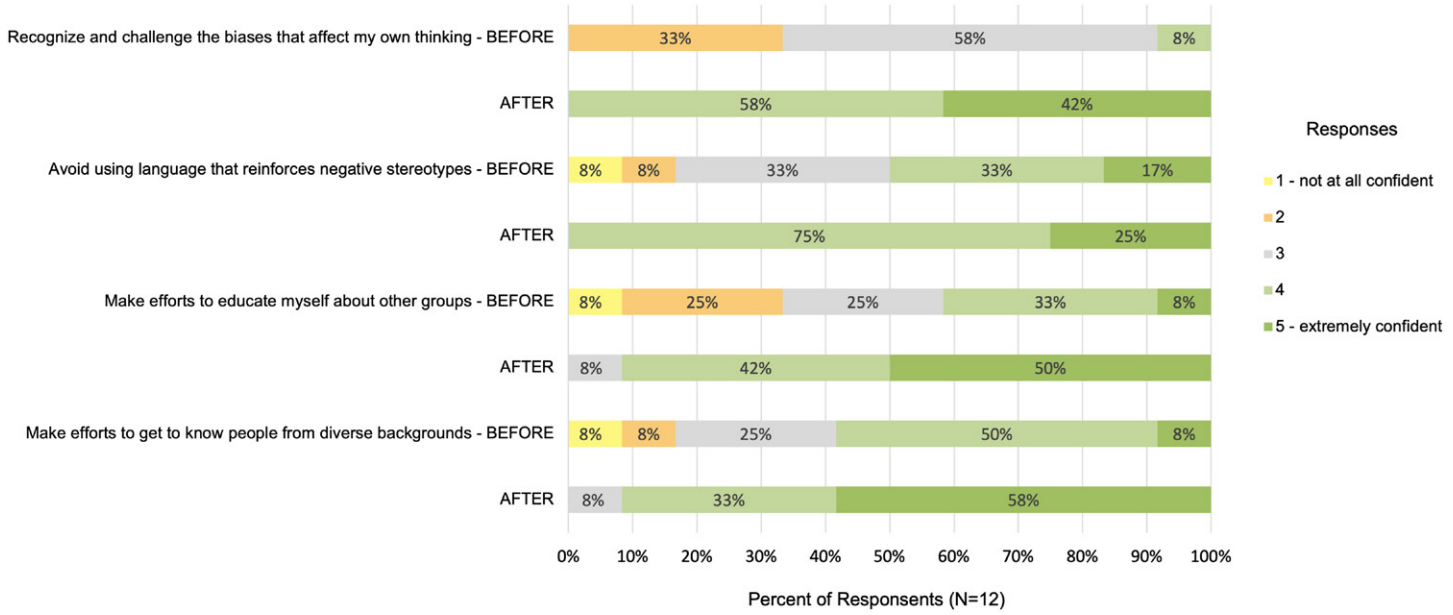

Fig. 4. Self-directed action distribution of items pre- and post-course, in response to the following prompt: "People can take a variety of actions to address issues of prejudice, discrimination, and injustices. Listed below are different actions. Indicate your level of confidence."

overall increases in confidence and valuation in these domains. For example, in the self-directed action subscale items, students only selected feeling "not at all confident" when thinking about before participating in the course, a response category that shrunk to zero when thinking about their feeling after participating in the course. Similarly, feeling extremely confident for an item became more frequently selected after participating in the course (e.g., Fig. 4).

We also used descriptive statistics and a paired *t* test to analyze differences in the before and after course composite subscale scores. There were no extreme outliers, and the differences of subscale scores were normally distributed according to the Shapiro–Wilk test (Shapiro and Wilk 1965), except for self-directed action and intergroup collaboration subscales. However, since *t* tests are robust to Type I errors, we elected to still use this approach. We nonetheless compared this analysis to the nonparametric Wilcoxon signed-rank test (Woolson 2008) for these two subscales, and the conclusions were the same, further indicating confidence in the results. All after-course subscale scores for intergroup collaboration and action were statistically significantly higher ($p < 0.05$) than the before-course scores, suggesting students experienced notable gains in these areas (see Table S3).

For the pedagogy-related scales, students predominantly indicated that the content (i.e., assigned readings, journals or reflection prompts, and other written assignments) and structural elements (i.e., structured activities and exercises, ground rules for discussion, small groups of students, diverse groups of students, and collaborative projects) of the course contributed very much to their learning. For all of these items, 50% or more of students selected a 4 or 5 (1 = did not contribute to learning at all, 5 = contributed very much to learning), with "other written assignments" being the lowest with 50% of students selecting 4 or 5, and "collaborative projects" being the highest with 92% of students selecting 4 or 5. Further, students also predominantly indicated that instructors were very effective across all items of the instruction subscale—every item had 85% or more of students selecting a 4 or 5 (1 = not at all effective, 5 = very much effective) (see Fig. 5). These results suggest that the course content, structure, and instructional style are a good fit for the goals of the course and student learning needs.

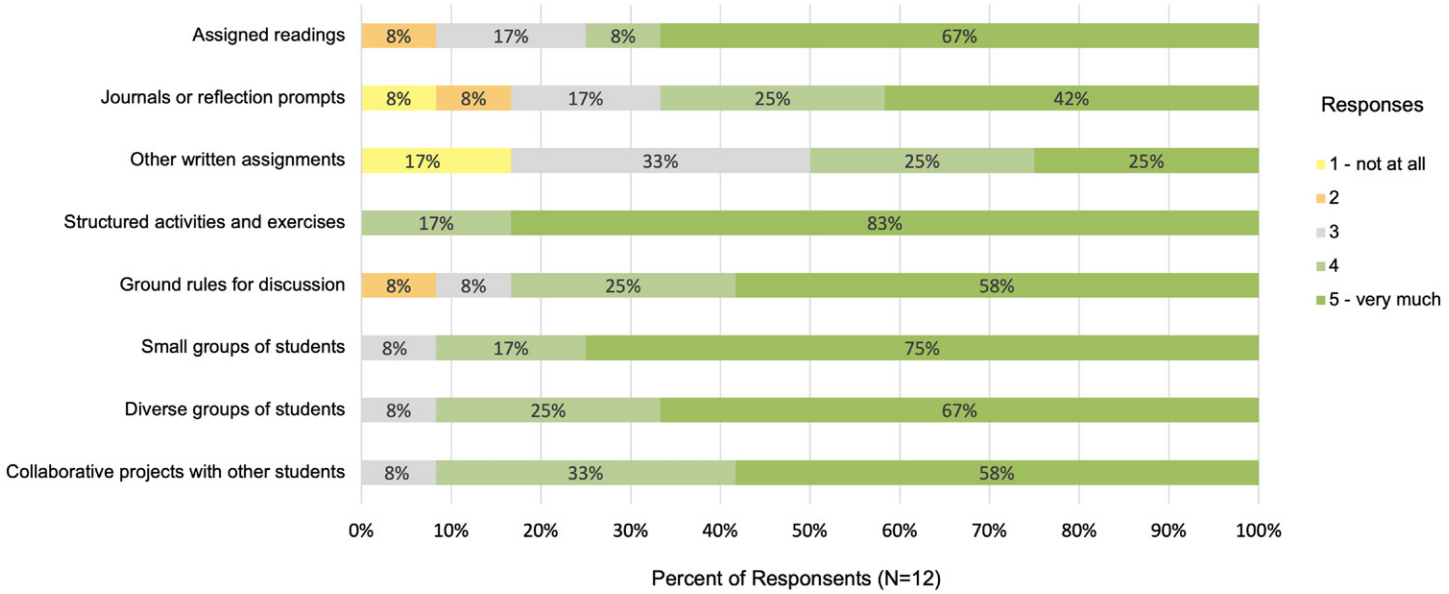

Fig. 5. Importance of content and structural elements for learning, *in response to the following prompt*: "Listed here are different educational features. How much did each component contribute to your learning in the course?"

Lessons learned on departmental adoption. Based on the findings from student surveys and our experiences implementing this course, we offer the following set of practical recommendations for adoptions.

1) *Identify instructor(s) with expertise in DEIAJ*. Our team has expertise implementing numerous DEIAJ initiatives including inclusive mentoring programs (e.g., Burt et al. 2023; Fischer et al. 2018), preventing sexual harassment, and transformative research experiences for marginalized students (Burt et al. 2016; Rasmussen et al. 2021). We also regularly participate in community conversations surrounding DEIAJ issues in the Earth sciences (e.g., Burt et al. 2022; Haacker et al. 2022; Morales et al. 2021). This experience helped us respond to many student questions in the moment based on familiarity with a wide swath of literature. Many institutions may need to further develop faculty competencies in order to deliver a course with the content outlined above. We also suggest that institutions consider inviting faculty with complementary DEIAJ expertise from outside of your department to co-teaching the course.
2) *Ensure the credit level of the course is consistent with other graduate classes*. Most graduate level courses in our department are offered as two-credit courses, and the course described above is consistent with the workload associated with two credit hours. This helps to set expectations for workload and indicates that this course is similarly challenging to other courses in our graduate program. New courses can be viewed as competing with existing courses for enrollment. Minimize this issue by avoiding scheduling conflicts. We also implemented this as two consecutive hours on one weekday. This avoided cutting off productive conversations.
3) *Implement this course using an in-person format*. This course was first implemented in Fall 2021 and offered in a face-to-face format. Given safety issues associated with the COVID-19 pandemic, we allowed students to join remotely as needed. Based on this experience, we strongly discourage a hybrid approach. It was difficult to maintain group discussion formats with one or two students online. We recommend an in-person format given research that online courses often have lower student participation without significant instructor effort (Reinholz et al. 2020).

4) *Acquire support for the initial class period designed to remove social barriers and for guest speakers*. As discussed above, ImprovScience designed and led a 2-h session to enable engaging and honest conversations about hard topics. We used techniques from that first class to maintain a safe and inclusive learning environment throughout the semester. There is a fee associated with this service, but similar expertise may be available through other institutions. We recommend seeking support for this early. We also had excellent feedback on guest lectures led by faculty members from outside the department with research expertise on critical race theory, disability, and accessibility, to name a few.
5) *Identify appropriate and impactful project options*. Students may need help identifying projects that are appropriate in scope, can be completed during the timeline of a semester, and have the potential for impact (locally or nationally). In the first iteration of the course, we gave students relatively little guidance to encourage creativity and introduced the project midway through the course. These choices required substantial iteration of project topics and projects that extended after the end of the semester. We recommend introducing the project early in the semester and providing clear guidelines and/or examples.

Looking forward

As a community, we can advance DEIAJ and achieve our goals if we incorporate it into the fabric of all aspects of scientific endeavors, including our educational and research practices. This will bridge the gap by creating entry points of engagement earlier and recognizing and valuing it as part of the scientific process. Quite simply, higher levels of engagement are needed to foster a diverse geoscience community. Oftentimes the people that are attracted to engaging in DEIAJ work are the most marginalized and directly impacted by the systemic inequities. The course we outlined above may be one step toward reducing capacity issues for DEIAJ efforts by helping graduate students have the awareness and skills to work on difficult problems. We would be remiss if we did not also acknowledge the recent politicization of DEIAJ efforts at all levels of education. DEIAJ is foundational to the core mission of higher education and skills in this realm are needed for problem-solving, decision-making, and leadership.

Acknowledgments. Support for this work was provided by the National Science Foundation through DCL: GOLD-EN EAGER 2039480. We would like to extend a thank you to ImprovScience and Affinity Arts Consulting for challenging us to engage in creative ways. We thank Christopher Atchison, Lynn Hempel, Nicole Kelp, Naomi Nishi, and Ian Castro who shared their experiences and expertise in the course.

Data availability statement. Evaluation data collected and presented in this article was conducted by the CSU STEM Center, which facilitates STEM education-based program, research, and evaluation activities. Access to our survey instrument via Mountain Scholar at https://hdl.handle.net/10217/236182.

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