Improving Undergraduate Climate Change Literacy Through Writing: A Pilot Study

By Jennifer D. Small Griswold

A climate-literate population, capable of making informed decisions related to climate change, is of critical importance as society faces ever-increasing global temperatures and changes in the climate system. This project evaluates the effectiveness of a novel instructional approach that incorporates climate change science into a first-year undergraduate level writing course. Science content included in the course focuses on climate and global environmental change and how it relates to society, policy, and economics. The multidisciplinary nature of the course material allows the climate change science content to be addressed from different viewpoints and student perspectives. Student surveys and self-reflections indicate that fundamental climate change science concepts and content can be taught in the context of a nonscience course focused on writing. Self-reflections reveal that 50% of students reported new or continuing interest in science and climate science, 35% did not explicitly mention their attitude toward science, 10% remained uninterested, and 5% lost interest as a result of participating in the pilot course. To produce climate literate citizens, new methods such as the pilot course described in this study, can be used to incorporate the science of climate change into nonscience instructional settings.

Writing academic papers is a fundamental part of the university experience, from an individual's initial entry as a first-year undergraduate through completing a senior thesis. Writing skills are also essential once students leave university because most, if not all, professions require written communication skills (Ellis, Taylor, & Drury, 2006). A well-developed ability to read critically and write coherently is essential for playing a role in the community and society as a whole. This concept can be focused specifically on the ability to read, write, and think about scientific and technological material, which plays an increasingly important role in daily life, political decisions, and social activities (Kolikant, Gatchell, Hirsch, & Linsenmeier, 2006). Our world is increasingly influenced and shaped by technological and scientific advancements and politically affected by scientific controversies. Students of all levels need to be able to read, view, and understand scientific information. Veron Marbach-Ad, Wolfson, and Ozbay (2016) highlighted the importance of incorporating climate change literacy into undergraduate education to prepare students for the future of a changing world.

This study assesses the potential impact of alternative teaching methods addressing climate science literacy at the undergraduate level and proposes an alternative method for exposing undergraduate students to climate change–related science through a first-year undergraduate writing course. This method capitalizes on the fact that most, if not all, undergraduates are required to complete a first-year composition course or another writing requirement to complete their undergraduate degree programs. By incorporating concepts and content related to climate change science in a writing course, students experience science in a nonscientific and nontraditional environment. Previous work by Jasanoff (2010) suggested that there is a place for nonscientific ways of knowing and experiencing climate and thus climate change that allows for experiential learning and the connection between science and social environments.

In an academic setting, science content is typically learned in a lecture or laboratory setting, often with an experimental or mathematical approach but with little interactive engagement (Deslauriers, Schelew, & Wieman, 2011; Hake, 1998; Knight & Wood, 2005). Not all undergraduate students are required to complete rigorous science coursework even though students are increasingly exposed to climate change science in the media and on the internet (Bell, 1994; Boykoff, 2007; Boykoff & Boykoff, 2007). Students entering the university and taking traditional science classes often bring with them misconceptions regarding the science content covered in their courses, whereas other students avoid science courses completely (Black, 2005; Philips, 1991). Traditional and social representations of climate change science are not often peer reviewed or fact checked (Boykoff, 2007; Corbett & Durfee, 2004), requiring students to evaluate and interpret science content outside of the traditional university textbook and peer-reviewed environment. Thus, a basic understanding of the science of climate change will assist students in making informed decisions about their actions and their impact on the environment.

Pilot course description and goals

The pilot course used in this study was an undergraduate writing course taught at a large public university in winter quarter 2007. The course fulfilled the composition writing requirement to graduate from the institution. Readings for the pilot course included sections from science textbooks, journal articles (e.g., *Science* and *Nature*), reports, popular books, magazines, and newspapers all related to global climate and environmental change issues.

The course incorporated innovative ideas to maximize student learning of both the writing process, science content, and critical thinking skills. During the pilot course students wrote five papers:

- a personal history describing their life and writing experiences,
- a reflective essay on a personal connection to a climate or environmental change issue,
- a research project about a climate change issue of personal interest,
- a persuasive letter to a local representative about a climate change issue of their choice, and
- a comparative analysis between a movie version of science and the actual science.

Students were evaluated based on writing assignments, in-class participation, and student self-evaluations (Black & Wiliam, 1998; Wiliam, 1998). Student understanding of science content and concepts were evaluated using a content test and in-class activities.

The fundamental objective of the instructional plan was to test the theory that science, at least basic climate change literacy, can be taught through a writing course. Students

TABLE 1

Comprehensive summary of pilot course participants.

Pseudonym	Gender	First language	Major field	Level	Grade
Rose	F	English	Bioinformatics*	Junior	A
Harry	M	Taiwanese	Art	Freshman	A
Fiona	F	English	Linguistics	Sophomore	A–
Veronica	F	English	Community Studies	Freshman	A–
Jamie	F	English	Environmental Studies	Freshman	A–
Tammy	F	English	Earth Science	Freshman	A–
Samantha	F	English	Art	Freshman	A–
Rebecca	F	Spanish	Psychology	Freshman	B+
Anthony	M	Russian	Biochemistry and Molecular Biology and Molecular, Cell and Developmental Biology	Freshman	B+
Jared	M	English	Earth Science*	Senior	B+
Clare	F	English	Undecided, Film	Freshman	B
Andrea	F	English	Health Sciences	Freshman	B
Adam	M	English	Undecided	Freshman	B
Marissa	F	English	Undecided	Freshman	B
Emily	F	English	Business Management Economics	Sophomore	B
Susan	F	English	Biology	Freshman	B–
David	M	English	Chemistry and Computer Engineering	Freshman	B–
Kevin	M	Russian	Computer Science*	Junior	B–
Barbara	F	Spanish	Sociology	Freshman	C+
Bonnie	F	Filipino	Biology	Sophomore	C+

Note. Those majors denoted with an asterisk (*) are officially declared. Freshman and sophomores technically have "proposed" majors and may change their mind at some later date (after the completion of the study).

TABLE 2

Categories describing the change in student self-associations with science and scientific material after participating in the pilot course.

Category	Descriptions	Representative quotation
U Uninterested	Expressed negative associations with science both before and after course	"In all honesty, the science in the course was never my main concern. I love the earth, and I intend to go out of my way to help protect it, but it has never been "my thing" to know the way the planet works."
L Lost Interest	Initial interest or curiosity dampened after course	"The only dislikes about this course are the following: Sometimes the readings were too scientific and I felt that I could not understand the point that the writer/s were trying to make."
I Interested	Expressed positive associations with science both before and after course	"What I liked about this course is that I had the advantage of teaching others about environmental science since I took this course last year."
G Gained Interest	Initial negative associations (lack of interest or fear) dispelled and replaced with interest and confidence	"With all honesty, I did not choose this class based upon its topic, but I sure am glad that I did. Not only did I get a handful of scientific knowledge, but I also learned a lot about writing I did not know. I never knew what logical fallacies were; I did not know exactly what global warming was, all I knew was that it was making the earth hotter. I have become more informed about what is going on in the environment I live in, and I gained knowledge about writing that I will be able to use in my future college career."

were not informed of this goal explicitly. They were introduced to the ideas and thought processes behind scientific thinking and exposed to new scientific concepts and issues related to the science of climate and environmental change each week. The overarching goals related to climate change literacy were broadly classified as *attitudinal*, *skills development*, and *content retention*. Therefore in this study, we address the following three broad questions:

1. Did students leave the course with a basic understanding of and familiarity with climate change science topics?
2. Did students develop skills that are useful for reading and writing scientific material related to climate change science?
3. What did students learn: general concepts or specific facts?

Course participants

Students in the pilot course were all undergraduates taking the course to satisfy the writing (composition) requirement. This requirement can be taken at any time even though it is traditionally a "first-year course." Table 1 provides a comprehensive summary of student gender, level of study, proposed or declared major, first language, and overall grade in the course. A total of 20 students completed the course with passing grades—six male students and 14 female students, with 14 freshmen, three sophomores, two juniors, and one senior. Their proposed or declared majors spanned both the sciences and the humanities. There were three official declared science majors (both juniors and the senior), seven proposed science majors (six freshmen and one sophomore), and 10 proposed nonscience majors (eight freshman and two sophomores). Note that writing courses at the institution are limited to 30 students or less to guarantee a high level of student–teacher interaction. Students did not receive grades on individual assignments; rather, their overall course grade was determined by a "portfolio" of all the work completed throughout the quarter.

Assessment tools and results

Assessment tools and methods, inspired by "backwards design" (Ellis et al., 2006; Wiggins & McTighe, 1998) and "formative assessment" (Black & Wiliam, 1998; Donovan & Bransford, 2005) included coding of written student work, self-evaluations, exam-style evaluations, and in-class activities. All coding of student work was completed by the author. These assessments were chosen to address the attitudinal, skills, and content goals related to climate and environmental change literacy and critical thinking.

Question 1: Attitudinal assessment

To determine attitudinal shifts regarding climate change science and their relationship with scientific information, the author collected and coded all papers and self-evaluations. Attitude shifts were divided into four broad categories:

- (U) *Uninterested*—not interested in science before and after the course,
- (L) *Lost Interest*—initially interested in science, became less interested in the course,
- (I) *Interested*—interested in science both before and after the

course, and
- (G) *Gained Interest*—uninterested before the course, became interested during course.

Table 2 displays the categories describing students' self-associations with science and scientific material. Student quotations in the table are from student papers in response to the final essay assignment "Where/who are you now as a writer? Reflections on your writer's history and self-evaluation" that is turned in at the end of the course.

Only 13 out of the 20 students discussed their attitude or relationship to science or scientific information in their self-evaluations. Of these 13, five were classified as "G," five were classified as "I," one was classified as "L," and two were classified as "U." Overall, self-reflections revealed that 50% of students reported new or continuing interest in science and climate science, 35% did not explicitly mention their attitude toward science, 10% remained uninterested, and 5% lost interest as a result of participating in the pilot course.

Question 2: Skills assessment

A fundamental part of the course plan was the development of a skill set students could apply to writing papers for most courses and for evaluating and understanding the scientific material in a variety of formats. The four main skills stressed in the course included organizational skills, revision techniques, researching, and evaluating sources. We determined whether students developed or improved these skills by analyzing student self-evaluations for comments related to the four skills categories. See Table 3 for an explanation of the categories describing comments related to skills development and an example student quote.

According to their self-evaluations, students felt they developed, improved on, or perfected the skills outlined in the pilot course plan. Seventeen out of 20 students (85%) made comments referring to one or more of the four skill types in their self-evaluations. Of the 17 students, the majority made more than one comment about the skills they learned or used in class. Figure 1 shows the total number of comments about each skill type. "Organizational skills" were the most frequently mentioned with a total of 16 comments. The second most frequently mentioned skill type was "researching" with 10 comments. Using library resources and searching for journal articles was a totally new experience for many first-year students. Both "revision" and "evaluation of sources" received a similar number of comments (six and seven, respectively). It is clear from these results that students learned new skills and improved their ability to write and think critically about climate change conctent.

Question 3: Content assessment

To determine if students were learning and retaining scientific concepts, a content test was administered in traditional science course format (multiple choice and short answer). This text was not included in the calculation of their final grade in the course. It was presented as an activity to test their understand-

TABLE 3

Categories describing discussion/comments regarding skills development or use throughout the pilot course.

Category	Descriptions	Representative quotation
O Organizing Material	Comments regarding their ability to organize or structure papers	"Yet, the biggest improvement I have seen in my papers is my ability to better organize my thoughts by incorporating "cut-n-paste" activities so that I can see how my paper would flow better. When I write my papers, I go back and add transition sentences wherever necessary to ensure that the reader can follow my train of thought, especially in my research paper."
R Revision Techniques	Comments regarding the ability to revise, reflect upon and edit their work	"Revision is very important because it makes a big difference if I revise my paper or not. Usually, after I revise my paper, my writing becomes easier to read and understand, and through the process of revision I also learn from my mistakes in writing."
S Researching	Comments regarding the ability to search for information, use library resources or the internet	"Specifically, writing a white paper taught me about research techniques. I learned how to use the resources available to me at the campus library. I have read scientific journals before, but I had never before searched databases for a variety of journals to use on a long scientific essay."
E Evaluating Sources	Comments regarding the ability to evaluate sources of information for reliability and applicability to assignments	"The main challenge that I faced throughout the course was finding useful sources and analyzing them. I've used the Internet as a means of research throughout high school, so I wasn't familiar with sources like peer-reviewed journal articles. I've found out that these journal articles are much more reliable than online articles."

FIGURE 1

Total number of comments from all student self-evaluations for each broad skill type category.

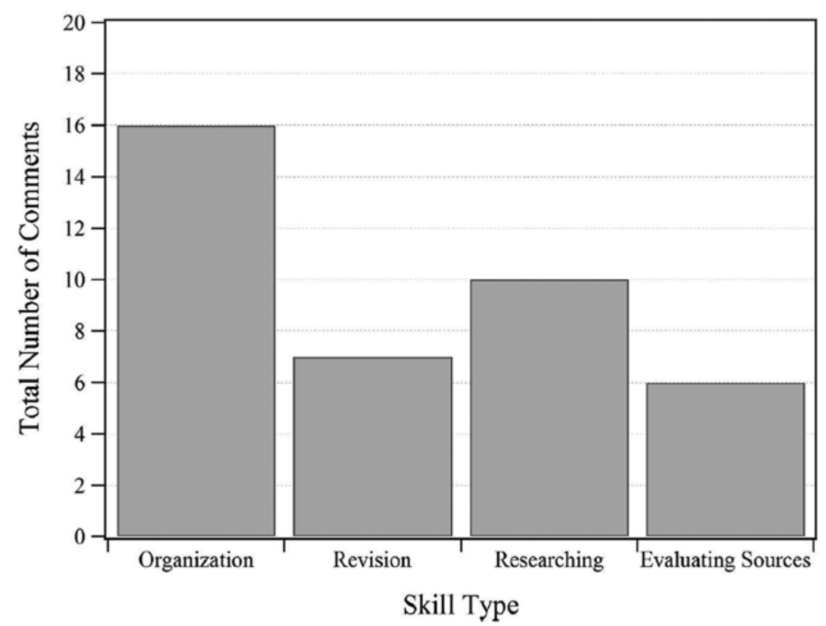
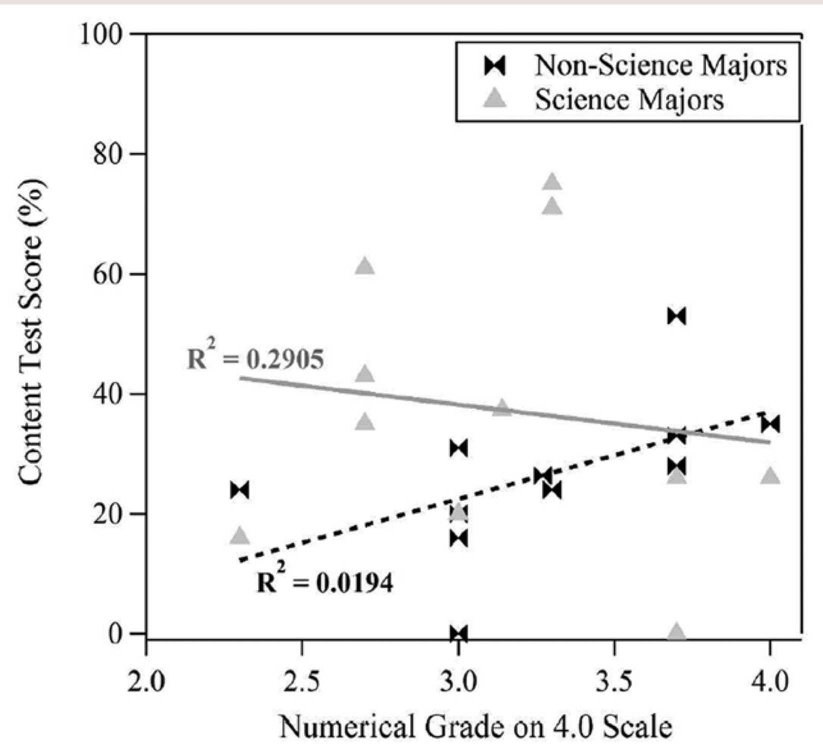


FIGURE 2

Results from the content test compared to final grade in course sorted by whether students were science or nonscience majors. Trend lines (with R^2 values) are as follows: black dotted lines for nonscience majors and solid gray lines for science majors.



ing. Therefore, the "grades" were merely a way for students, and for the instructor, to assess how much science content they were learning while writing. The questions were identical to those asked on exams for an Earth Science course taught at the same institution. An example short-answer question was "List the two factors that contribute to sea level rise in a warming climate, and describe how they do so." An example multiple-choice question was "Which of the following would decrease the albedo of the earth-atmosphere system? a) less cloud cover, b) glacial shrinking, c) reduction of snow cover, d) all of the above, e) none of the above." The maximum grade possible on the test was 25.5 points. With an average score of 35% (highest score 75%, lowest score 15.7%), students demonstrated limited retention of discrete facts discussed or read during the course. The data were evaluated as a function of the overall course grade (using the numerical 4.0 scale format) and further sorted by whether students were science or nonscience/undeclared majors (Figure 2).

In Figure 2, we see that there is a positive correlation between final course grade and the score on the content test for nonscience majors, whereas there is a slightly negative correlation for science majors. The average score for nonscience majors on the content test is 29%, whereas the average final course grade is 3.3 (a B+). The average score for science majors on the content test is 41%, whereas their average final course grade is 3.1 (approximately a B). One possibility to explain this difference is that science majors focused more on the content than the requirements for the assignments.

Assessment summary

A summary of the student assessment results can be found in Table 4. It shows which students' responses were coded into the different attitudinal and skills categories. As noted previously, it is clear that not all students mentioned skills or attitudinal shifts. Also, as a reminder, the content scores were not included in the calculation of the final grade. It is presented here in this table to identify possible links between successful science content understanding and liklihood of discussing attitudinal shifts or skills in their self-reflections.

Discussion and conclusions

The goal of this pilot course was to test the feasibility of teaching climate change science in a nonscience classroom setting. Using scientific readings from a spectrum of reputable sources allowed students to engage with climate change topics on a weekly basis. The success of this pilot course in increasing awareness of climate change issues demonstrates that it is possible to learn basic science content, specifically climate change science, through a writing course. Even though most students performed poorly on the content test, they were more aware of environmental issues after taking the course than before and actively voiced their pleasure of knowing more about popular science topics and those published through general and social media outlets. Students were interested in knowing more about environmental issues that personally affected them or their families, demonstrating the power of student interest and ownership in learning. Student papers, self-evaluations, and in-class activities provided insight into the three broad questions motivating this work.

1. Did students leave the course with a basic understanding of and familiarity with climate change science topics? Yes, students received an introduction to climate change science by reading and writing about a variety of global climate and environmental change topics in a writing course as opposed to a traditional science course. Throughout the course, they gained confidence in their ability to understand and interpret scientific material related to climate change science. By completing course assignments and activities, students interacted with climate change topics in a variety of formats. By formatting assignments with both personal and local/regional aspects, students were able to connect climate science with their daily lives and personal experiences.

2. Did students develop skills that are useful for reading and writing scientific material? In students' course self-reflections they noted papers were easier to write when they were genuinely interested in the topic, even if it was science based (Hounsell, 1984). They self-assessed improvements in their organizational skills, researching abilities, and ability to determine if a source was appropriate for use in an academic setting. They learned to interpret media representations of climate change science and make conscious and educated decisions about their reliability. It is clear that students felt they learned new skills, thereby improving their ability to write and think critically about the scientific content presented in the course readings and assignments. These skills were designed to help them interpret and assess climate science, and scientific material in general, presented in future courses or experienced in their daily life.

TABLE 4

Summary of pilot course participants' assessments.

Pseudonym	Grade	Attitudinal category	Skills	Content (%)
Rose	A		R, O, S	26
Harry	A		O, E, S	35
Fiona	A-	G	E, 2R, 3O	53
Veronica	A-		S, E	33
Jamie	A-		O, 2S	26
Tammy	A-	I	2S, O	
Samantha	A-	G	S	28
Rebecca	B+	U		24
Anthony	B+	I		75
Jared	B+	I	E	71
Clare	B	G	O, R	16
Andrea	B	G	2O	20
Adam	B		S, E	31
Marissa	B	G	O, R	20
Emily	B	L/G	2O, E	
Susan	B-	I	O	61
David	B-	U	O, S, R	43
Kevin	B-			35
Barbara	C+	I		24
Bonnie	C+		R, O	16

Note. Content percentiles were calculated with a maximum score of 25.5 points for five questions with multiple parts. Content tests were graded in the equivalent scoring system for an upper division Earth Science course. See Tables 2 and 3 for key to letters in "Attitudinal category" and "Skills" columns.

3. What did the students learn: more general concepts or specific facts? Students were able to write coherently and accurately about scientific concepts in their research papers and use this information to write persuasive letters to government officials, local community organizations, and university officials. When given time and guidance to research and then to describe climate change topics accurately in each of the four papers focusing on climate change science, they did so successfully. The results of the "content test" midquarter showed that some students mastered both basic concepts and specific facts discussed in the course. Unfortunately, the average content test score of 35% demonstrates that the learning of discrete and specific facts was not as successful as developing a broad understanding of climate change.

Throughout the course and the analysis process, we learned that students can be engaged in, learn from, and enjoy the discussion of science and science content in a nonscience course setting. As mentioned earlier, writing courses at the institution are restricted to a maximum of 30 students. To address the limited sample size, we plan to offer this course in the future to increase the number to student responses. With a larger sample size, we hope to investigate differences in gender and first language. We also plan to incorporate a pretest (at the beginning of the course) to understand their initial content knowledge base, a midsemester content test, and a final content test. Additionally, we plan to use 6-month and 1-year follow-up surveys to assess long-term climate change science content retention. We believe this work is particularly relevant from a science and educational perspective and that it contributes to the general body of work advancing our understanding of how students can learn science through alternative methods of student engagement. ■

References

Bell, A. (1994). Media (mis) communication on the science of climate change. *Public understanding of science*, *3*, 259–275.

Black, A. A. (2005). Spatial ability and earth science conceptual understanding. *Journal of Geoscience Education*, *53*, 402–414.

Black, P. J., & Wiliam, D. (1998). Assessment and classroom learning. *Assessment in Education: Principles Policy and Practice*, *5*(1), 7–73.

Boykoff, M. T. (2007). From convergence to contention: United States mass media representations of anthropogenic climate change science. *Transactions of the Institute of British Geographers, 32,* 477–489.

Boykoff, M. T., & Boykoff, J. M. (2007). Climate change and journalistic norms: A case-study of US mass-media coverage. *Geoforum*, *38*, 1190–1204.

Corbett, J. B., & Durfee, J. L. (2004). Testing public (un)certainty of science media representations of global warming. *Science Communication*, *26*, 129–151.

Deslauriers, L., Schelew, E., & Wieman, C. (2011). Improved learning in a large-enrollment physics class. *Science*, *332*(6031), 862–864.

Donovan, M. S., & Bransford, J. D. (2005). Introduction. In M. S. Donovan & J. D. Bransford (Eds.), *How students learn: History, mathematics, and science in the classroom* (pp. 1–28). Washington, DC: National Academies Press.

Ellis, R. A., Taylor, C. E., & Drury, H. (2006). University student conceptions of learning science through writing. *Australian Journal of Education*, *50*, 6–28.

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. *American Journal of Physics*, *66*, 64–74.

Hounsell, D. (1984). Contrasting conceptions of essay-writing. In R. Marton, D. Hounsell, & H. Entwistle (Eds.), *The experience of learning: Implications for teaching and studying in higher education* (3rd ed., pp. 106–125). Edinburgh, Scotland: University of Edinburgh.

Jasanoff, S. (2010). A new climate for society. *Theory, Culture, & Society*, *21*(2/3), 233–253.

Knight, J. K., & Wood, W. B. (2005). Teaching more by lecturing less. *Cell Biology Education*, *4*, 298–310.

Kolikant, Y. B.-D., Gatchell, D. W., Hirsch, P. L., & Linsenmeier, R. A. (2006). A cognitive-apprenticeship-inspired instructional approach for teaching scientific writing and reading. *Journal of College Science Teaching*, *36*(3), 20–25.

Philips, W. C. (1991). Earth science misconceptions. *Science Teacher*, *58*(2), 21–23.

Veron, D. E., Marbach-Ad, G., Wolfson, J., & Ozbay, G. (2016). Assessing climate literacy content in higher education science courses: Distribution, challenges, and needs. *Journal of College Science Teaching*, *45*(6), 43–49.

Wiggins, G., & McTighe, J. (1998). *Understanding by design*. Alexandria, VA: Association for Supervision and Curriculum Development.

Wiliam, D. (1998). An overview of the relationship between assessment and the curriculum. *Assessment in Education: Principles. Policy and Practice*, *5*(1), 1–11.

Jennifer D. Small Griswold (smalljen@hawaii.edu) *is an assistant professor in the Atmospheric Sciences Department at the University of Hawaii at Mānoa in Honolulu.*