Concept Mapping Workshops

Helping Ocean Scientists Represent and Communicate Science

BY ANNETTE deCHARON, LINDA DUGUAY, JANICE McDONNELL, CHERYL PEACH, CARLA COMPANION, CHRISTEN HERREN, PATRICIA HARCOURT, THEODORE REPA, CARRIE FERRARO, PATRICIA KWON, SAGE LICHTENWALNER, ERIC SIMMS, AND LYNN WHITLEY

ABSTRACT. Public appreciation and basic understanding of the role the ocean plays in the global environment has become more important as the urgency to make decisions on complex environmental issues has increased. Because communicating science to the public is often challenging for scientists, they can benefit from employing methods such as concept mapping, which "deconstructs" science into discrete ideas and organizes them into graphical formats. Responding to recommendations by ocean science faculty who participated in concept-mapping workshops with pre-college educators, four Centers for Ocean Sciences Education Excellence designed, implemented, and evaluated a series of professional development workshops for graduate students. These workshops engaged 20 faculty-level ocean scientists to help 73 graduate students depict complex scientific ideas using concept maps. Evidence shows that operationally breaking down topics and reorganizing them into graphical formats benefited faculty and graduate students alike. Each workshop culminated with the graduate students delivering oral presentations to nonscientist audiences such as high school students. Graduate students were highly rated on their abilities to place topics within a broad societal context. In a follow-up survey, graduate students recognized the potential of concept mapping to enhance their professional skills and to organize their own research.

BACKGROUND

In her 1998 Presidential Address to the American Association for the Advancement of Science, Jane Lubchenco called upon scientists to enter a "social contract" because society's formidable environmental challenges "require substantial information, knowledge, wisdom, and energy from the scientific community." The National Science Foundation (NSF) also recognized the need for scientists to engage and inform the public to meet the "nation's critical need for a citizenry literate in science and technology" (NSF, 2006). *Science* Executive Publisher Alan Leshner (2007) called upon scientists in an editorial to engage in "a genuine dialogue with our fellow citizens about how we can approach their concerns and what specific scientific findings mean."

Engaging in dialogue with nonscientists, however, can present a daunting challenge for scientists. Gene Likens, a 2001 National Medal of Science recipient, concluded that when faced with the "difficult but crucial task of clearly communicating evidence-based information," scientists are frequently "hindered by poor communication—including an excessive reliance on acronyms and jargon" (Likens, 2010). In a 2009 review of social sciences research, Nisbet and Scheufele (2009) found that "effective communication [necessitates] connecting a scientific topic to something the public already values or prioritizes, conveying personal relevance. And in people's minds, these links are critical for making sense of scientific information." Likewise Lubchenco (1998) asserts, "as the magnitude of human impacts on the ecological systems of the planet becomes apparent, there is increased realization of the intimate connections between these systems and human health, the economy, social justice, and national security."

Recognizing the imperative to bridge the gap between ocean science content experts and lay audiences, the Centers for Ocean Sciences Education Excellence (COSEE) have facilitated professional development of ocean scientists in the pedagogical technique of "concept mapping." Concept maps are powerful tools for visualizing, organizing, and linking ideas and processes. By displaying the relationships among concepts using connecting lines and descriptive phrases, complex science can be broken down into its constituent underpinnings, providing a type of "road map" for researchers to clearly organize and explain the logic of their science. Figure 1 illustrates how such maps are constructed at the basic level.

The process of concept mapping was pioneered in the 1960s by cognitive researcher Joseph Novak to visually display children's dynamic knowledge structures as they were introduced to basic science concepts (Novak and Gowin, 1984; Roth and Roychoudhury, 1993; Novak and Cañas, 2008). For content experts, such as the ocean scientists who participated in the Faculty-Graduate Student Collaborative (FGSC) workshop series, concept maps can illustrate not only their extensive knowledge, but also "how they organize, represent, and interpret information in their environment" (Bransford et al., 2000), providing visualizations of "the geography of an intellectual space" (National Research Council, 2006).

While it has been shown that concept maps are an effective method for teaching undergraduates complex science content (Arnaudin et al., 1984; Ault, 1985; Cilburn, 1990; Novak, 1990; Briscoe and LeMaster, 1991; Mahler et al., 1991; Markow and Lonning, 1998; McClure et al., 1999; Rebich and Gautier, 2005), the use of this tool as an aid to researchers seeking to find effective ways to make their work accessible to a broader audience has to date not been investigated. This article describes the development, implementation, and testing of the FGSC workshop model that employed concept mapping to help graduate students represent and communicate complex science to nonscientists. The results of this study suggest that this approach is an effective strategy that can be readily used, in partnership with education professionals, by scientists interested in developing clear and informative science presentations for the public.

DESIGN OF THE FACULTY-GRADUATE STUDENT COLLABORATIVE WORKSHOP MODEL

The FGSC model (Figure 2) is based on six COSEE-Ocean Systems (OS) pilot workshops that brought together faculty-level scientists and pre-college educators as peers to codevelop concept maps. Post-workshop evaluation surveys of participating scientists, both written and oral, revealed that they found concept mapping helped them to quickly convey their science messages to educators (deCharon et al., 2009). Several scientists

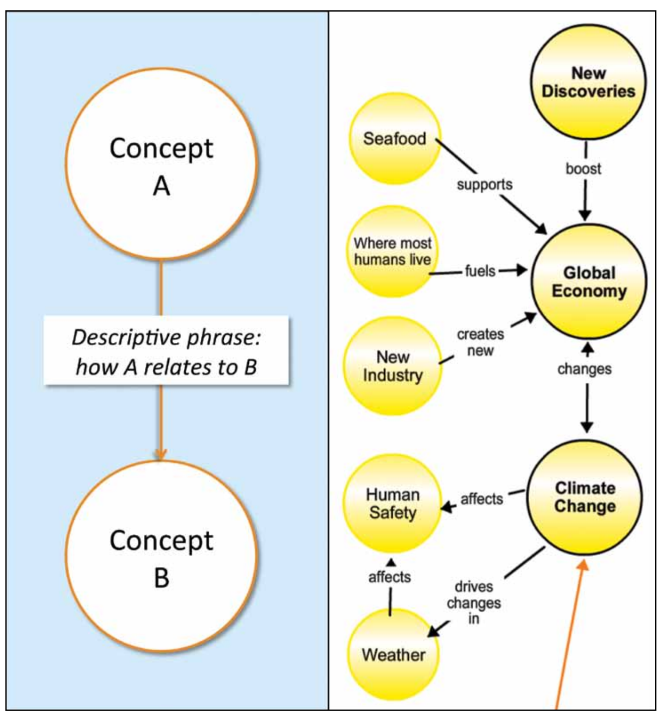

Figure 1. (left) Concepts, connections, and linking phrases that illustrate relationships between concepts are the fundamental parts of a concept map. (right) A portion of a concept map created at a Faculty Graduate Student Collaborative (FGSC) workshop. All 40 maps created during the workshops can be viewed at: http://cosee.umaine.edu/coseeos/workshops/fgsc.htm.

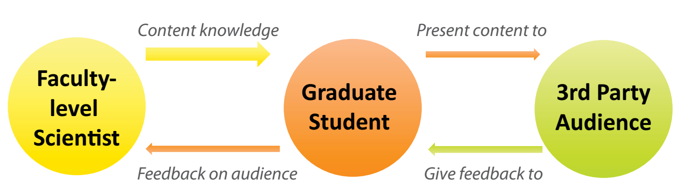

Figure 2. The FGSC model, in which faculty and graduate students engage collaboratively to create concept maps and present those maps to third-party audiences of nonscientists.

recommended that concept mapping be taught to graduate students in science fields, specifically mentioning that the technique could help these emergent scientists—at a critical point in their professional training—better convey how their research fits into the "bigger picture" of science and society.

Building on this workshop model, ocean scientists' recommendations, and evaluation results from a pilot workshop held in February of 2010 at the University of Maine's Darling Marine Center, the COSEE team designed the FGSC workshops with the following strategies in mind:

- Apply pedagogical techniques to ocean sciences content primarily through the use of concept mapping but also with targeted activities directed to how people learn, common preconceptions, and discussion of "homework" exercises that include asking nonscientists about basic ocean sciences content (see Box 1)
- Use a simple rubric worksheet both to give and to receive feedback about concept-map presentations in four categories: (1) big picture, (2) jargon, (3) organization of the concept map, and (4) take-home message.

Using these strategies, from April to October 2011, FGSC workshops were run at three COSEE Centers around the country: COSEE West at the University of Southern California (USC), COSEE Networked Ocean World (NOW) at Rutgers University, and COSEE California at Scripps Institution of Oceanography (see photos at end of article). In coordination with facilitators at each COSEE hosting the workshop, COSEE-OS staff cofacilitated these workshops to help provide continuity among the events. FGSC workshop participants were faculty-level ocean scientists and graduate students. Table 1 shows the locations, participant numbers, and third-party audience types for each workshop.

Pre-workshop application surveys were administered to the graduate students toward understanding their academic training, fields of study, confidence in presenting/translating scientific

BOX 1 | PEDAGOGICAL ACTIVITIES USED DURING FGSC WORKSHOPS

HOW PEOPLE LEARN

Participants were guided through a series of activity stations, each employing a different part of the "learning cycle" to present the same science topic. Post-activity, they discussed how each method might affect students' individual learning styles (Lawrence Hall of Science, 2008).

COMMON PRECONCEPTIONS

Participants considered strategies for dealing with students' preconceptions and their influential role in determining how people learn best, in part by discussing the video *A Private Universe* (Schneps and Sadler, 1988) and conducting hands-on activities investigating salinity, temperature, and water density.

"HOMEWORK" EXERCISE

Participants interviewed nonscientists, asking them two open-ended questions about basic ocean concepts. Group discussion of the responses reinforced that scientists need to first understand their audiences' knowledge base in order to effectively convey complex science content.

Annette deCharon *(annette.decharon@maine.edu) is Senior Marine Education Scientist, University of Maine, Darling Marine Center, Walpole, ME, USA.* **Linda Duguay** *is Director of Research, University of Southern California (USC), Wrigley Institute for Environmental Studies, and Director, USC Sea Grant Program, Los Angeles, CA, USA.* **Janice McDonnell** *is Associate Professor, Department of 4-H Youth Development, Rutgers University, Institute of Marine & Coastal Sciences, New Brunswick, NJ, USA.* **Cheryl Peach** *is Director, Scripps Educational Alliances, Scripps Institution of Oceanography, University of California, San Diego, La Jolla, CA, USA.* **Carla Companion** *is Research Associate, University of Maine, Darling Marine Center, Walpole, ME, USA.* **Christen Herren** *is Research Associate, University of Maine, Darling Marine Center, Walpole, ME, USA.* **Patricia Harcourt** *is COSEE-West Program Manager, USC, Wrigley Institute for Environmental Studies, USC Sea Grant Program, Los Angeles, CA, USA.* **Theodore Repa** *is Professor and Chair, Administration & Instructional Leadership, Graduate School of Education, Touro College and University System, New York, NY, USA.* **Carrie Ferraro** *is Project Coordinator, Coastal Ocean Observation Lab, Rutgers University, New Brunswick, NJ, USA.* **Patricia Kwon** *is Program Evaluator, COSEE-West, Los Angeles, CA, USA.* **Sage Lichtenwalner** *is Data Translator, Coastal Ocean Observation Lab, Rutgers University, New Brunswick, NJ, USA.* **Eric Simms** *was Science Education Specialist, Scripps Institution of Oceanography, UCSD, La Jolla, CA, USA (now at Harvard University Center for the Environment).* **Lynn Whitley** *is Director of Pre-College Education and Co-Director of COSEE-West, USC, Wrigley Institute for Environmental Studies, USC Sea Grant Program, Los Angeles, CA, USA.*

information to general audiences, experience as educators, and to obtain their feedback on pre-selected ocean literacy and climate literacy statements (National Geographic Society, 2005; NOAA, 2008). During an orientation session held the afternoon before the graduate students arrived, faculty members were given an overview of the graduate students' combined responses to the pre-workshop application survey. Faculty used the graduate students' responses to ocean and climate literacy statements to help draft their preliminary concept maps. Preliminary "Scientists' Maps" are online at http://cosee.umaine.edu/coseeos/workshops/fgsc.htm.

The typical format for the FGSC workshops was as follows:

- *Afternoon of Day One* – Faculty were first trained in how to create concept maps. Then they created and shared their preliminary maps, designed for that workshop's third-party audience, with peers and COSEE staff to receive constructive feedback.
- *Morning of Day Two* – Faculty scientists presented their preliminary concept maps to the graduate students, who rated the presentations using a standard four-category rubric described previously. Figure 3 shows one example of a preliminary map about climate records made by a USC scientist for an intended audience of high-school students. The map is organized according to the four-step sequence outlined at left in the figure, from top to bottom (i.e., climate interactions, records, decoding, processes).
- *Afternoon of Day Two* – Faculty and graduate students were placed in small teams, typically one faculty member per three students. Together, each team: (1) learned about specific aspects of pedagogy through workshop activities, (2) discussed and adjusted the faculty member's preliminary concept map for the third-party audience, and (3) created digital interactive copies of the new concept map using COSEE-OS software. After the interactive concept maps were developed, graduate students did "practice talks" in front of peers, scientists, and facilitators. They were given verbal feedback—particularly on how well they addressed the rubric components (i.e., big picture, jargon, map clarity, and "take-home" message). The graduate students refined their presentations and maps that evening and the next morning. For each workshop, COSEE facilitators noted consistent improvements between "practice talks" and the graduate students' final presentations on Day Three.

Figure 4 shows the consensus map that resulted from discussions between the author of the Figure 3 map and graduate students who were part of a collaborative team. In addition to reducing the overall number of concepts, the map is organized in a more hierarchical manner

Table 1. FGSC Workshop Locations, Participants, and Third-Party Audiences

	Ocean Systems (OS)	West	Networked Ocean World (NOW)	California
Month/Year	February 2010	April 2011	May 2011	October 2011
Participants' Home Institutions	University of Maine, Bigelow Laboratory for Ocean Sciences	USC, UCLA, Cal State Long Beach, Cal State Fullerton	Rutgers University	Scripps Institution of Oceanography
Number of Graduate Student Participants	17	20	20	16
Number of Faculty Scientist Participants	5	5	5	5
"Third Party" Audience*	High School Students	High School Students	Informal Education Audiences (using experts in informal science education as proxies)	Undergraduate Students (both science and nonscience majors)

*Third-party audience (5–40 people) types were chosen for either their relative closeness in age to the graduate students (e.g., undergraduates or high school students) or the fact that both the faculty and the graduate students were unlikely to have worked extensively with them (e.g., nonscientists in informal education settings such as museums, aquariums, science centers, or in non-graded after-school programs). The third-party audiences were an integral part of the FGSC workshops, in each case representing both a motivation and a set of specific constraints for the graduate students' presentations.

with “Climate” at top and “Human Impacts” at bottom. Guiding questions and a Leonardo da Vinci quote were added to make the map more engaging for high-school audiences. Media from the COSEE-OS database were employed to illustrate the details of map concepts (Figure 5).

- *Morning of Day Three* – In teams, graduate students presented their modified interactive concept maps directly to third-party audiences or, in the case of the COSEE NOW workshop, to experts in informal science education who served as proxies for informal audiences. Third-party audiences and other graduate students (the latter providing peer-level feedback to their fellow graduate students) used the same written criteria to rate the teams' final presentations as were used on the morning of Day Two to rate faculty members' presentations.

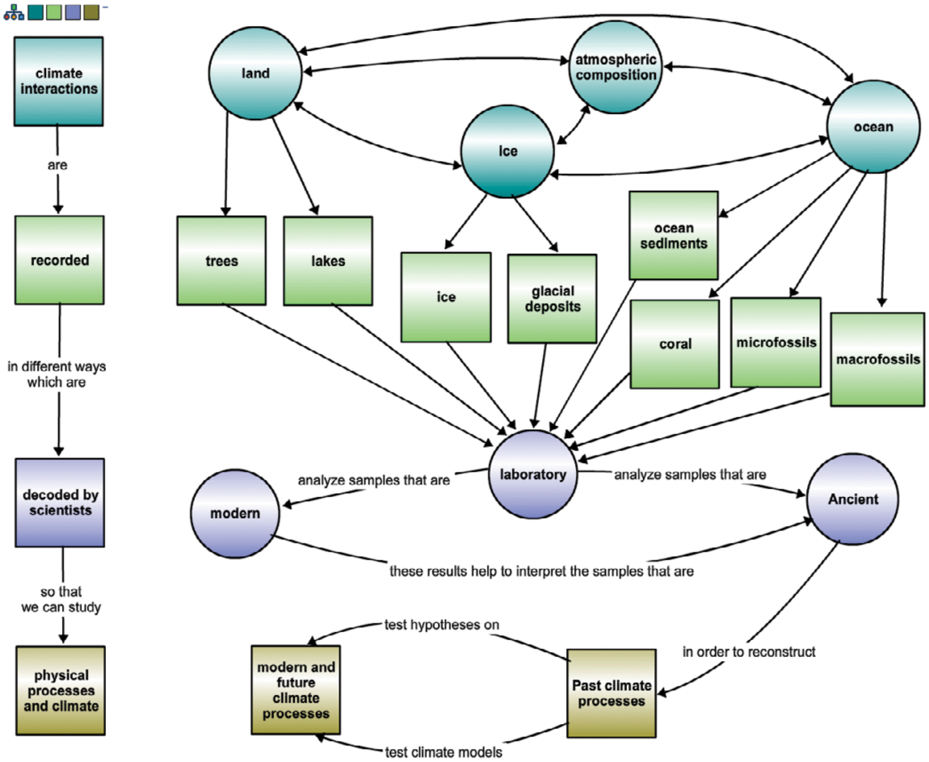

Figure 3. Example of a preliminary concept map. This map is intended to break down into the simplest form the different types of climate records scientists use and to show where the data come from. The COSEE-OS software used to construct this preliminary map (http://cosee.umaine.edu/climb) allows the presenter to sequentially reveal the various components by clicking the color-coded blocks at upper left. The intended audience for the final presentation was high school students.

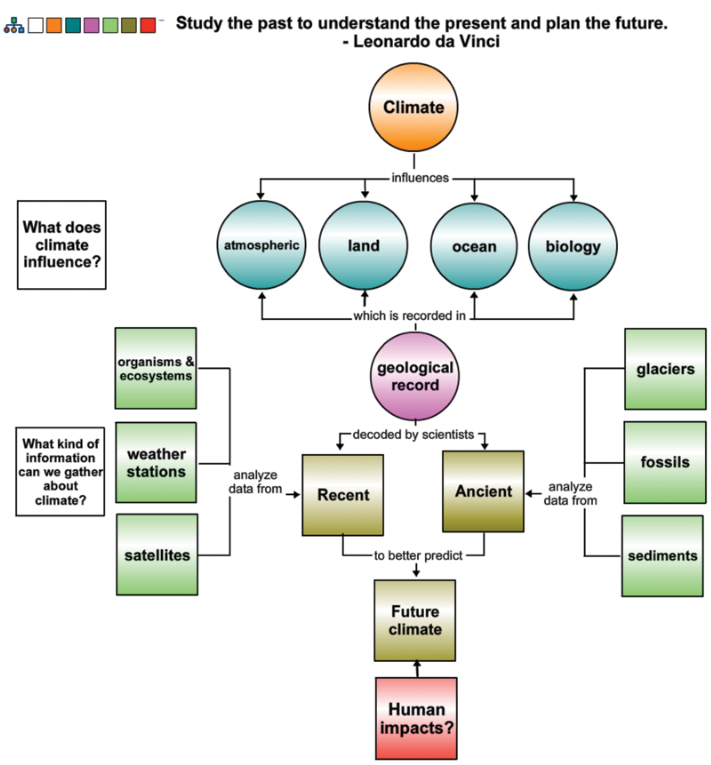

Figure 4. “Consensus” version of the Figure 3 map revised collaboratively with graduate students during the FGSC workshop. This version has been broken into two sections: what climate influences and what types of information can be gathered about climate from those records.

FINDINGS

Data were collected at the end of each workshop from graduate students via online surveys to evaluate how the project had met the following objectives: (1) organize the workshop to clarify how concept mapping can be used to present content, (2) train graduate students to deconstruct complex science and “think through topics” using concept maps, and (3) foster collegial interactions between graduate students and faculty members. In addition, during each workshop, faculty and graduate students both gave and received feedback on concept-map-based presentations with the objective of (4) assessing whether concept maps can be used to give effective presentations to nonscientists. In a follow-on survey, graduate students provided feedback on longer-term goals of this project, including the application of workshop content and/or skills for educational outreach, teaching, and their scientific research.

Graduate students (n = 71) gave an average rating of 5.9 out of a maximum 7.0 points using the Likert scale when evaluating Objective 1. On average, 85% (n=71) agreed that concept mapping helped them "think through topics" while preparing presentation materials for nonscientists. This evidence supports that the project successfully trained graduate students to view concept mapping as an effective method to deconstruct and analyze complex science (Objective 2).

The workshop design appears to have been very effective in terms of fostering collegial interactions between graduate students and faculty-level scientists (Objective 3). On average, 90% (n=71) of graduate students agreed that they "interacted as peers/colleagues" while creating concept-map-based presentations to meet the needs of third-party audiences. A related question asked of graduate students—"How would you rate the quality of interaction between scientists and graduate students during the workshop?"—received an average rating of 6.5 out of a maximum 7.0 points on the Likert scale. These outcomes—along with the positive feedback from participating faculty members—support the overall efficacy of the workshops' design in fostering a collaborative atmosphere for graduate students and faculty members. Some participating faculty members specifically mentioned concept mapping's value in representing not only what they know but also how they think about science. Thus, evidence indicates that concept mapping has great potential as a tool for scientists at various career stages to share, analyze, and develop ideas related to ocean science research.

Communication of Science Concepts

All workshop participants (i.e., faculty members and graduate students), as well as third-party audiences (Table 1), used a simple rubric worksheet to provide feedback on concept-map-based presentations. Presenters were rated on ability to put ocean sciences research into a "big picture" context, use of jargon, organization of the concept map, and clarity of their "take-home" messages. On Day Two of the workshop, all graduate students rated individual faculty members' presentations. On Day Three, all third-party audience members rated graduate student team presentations, and fellow graduate students provided peer-level feedback. Thus, during the workshop, graduate students transitioned from being "reviewers" to themselves being "reviewed" in order to help them quickly grasp how concept maps can be used to give effective presentations to a third-party audience.

Figure 6 shows data for the graduate students' final presentations, by audience, for all workshops (n=547 is the number of responses, with each responder rating several presentations), using a five-point Likert scale. Overall, the data are quite consistent among audiences: the overall range is only 1.03 points out of a total possible range of 4. In general, audiences rated graduate students' presentations highest in terms of "big picture" and lowest in terms of "take-home" message. Graduate students' ratings of their peers' concept-map-based presentations (n = 283; orange data in Figure 6) were remarkably consistent with an overall range of only 0.26 out of a total possible range of 4, indicating graduate students looked favorably on their peers' abilities to present using concept maps.

Thus, the FGSC workshop model clearly had multiple positive outcomes related to graduate students' use of concept maps as presentation tools. Graduate students were able to successfully communicate science to a variety of audiences, particularly in terms of placing information into a "big picture" context for nonscientists (Objective 4). They recognized that concept maps are viable means of conveying complex material and also enjoyed the experience of sharing their end products with nonscientists. Some graduate students mentioned that presenting information

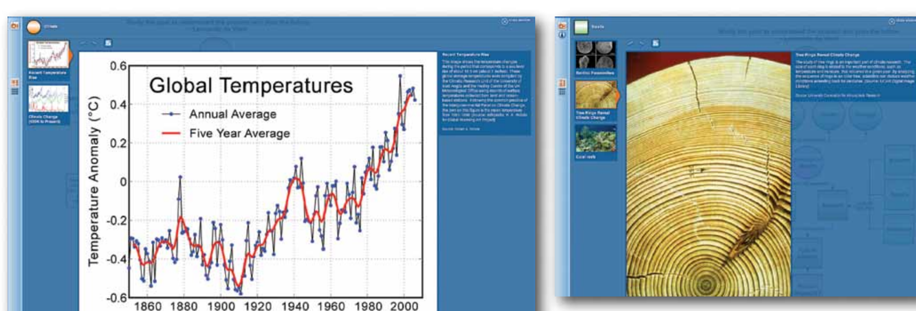

Figure 5. Examples of two "database assets" that the team linked to concepts on the map shown in Figure 4: (left) a time-series graph of global temperature rise linked to the "climate" concept, and (right) an image of a tree ring linked to the "fossil" concept.

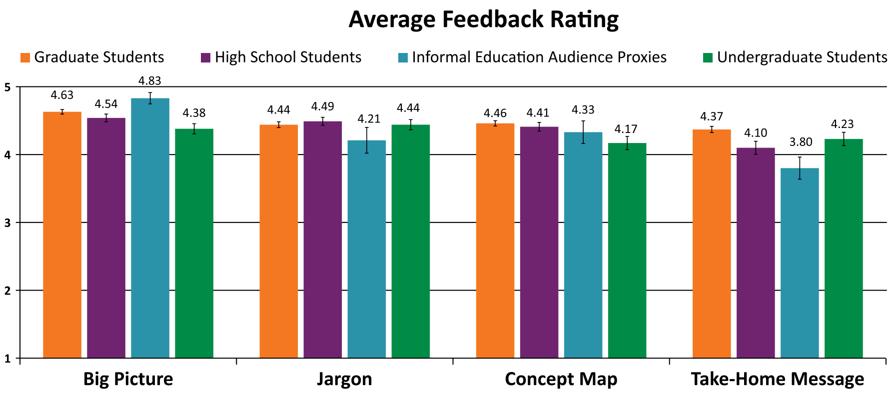

Figure 6. Average feedback ratings on graduate student teams' concept-map-based presentations on a 5-point Likert scale. Feedback from fellow graduate students is shown in orange and other colors correspond to third-party audiences (i.e., purple for high school students, blue for informal education audience proxies, and green for undergraduate students). Lower values (i.e., 1 or 2) correspond to less effective delivery, and higher values (i.e., 4 or 5) correspond to more effective delivery in each presentation category. See Table 1 for more information on participants and the third-party audiences.

to nonscientists in the form of concept maps allowed them flexibility in choosing "where to start" and "where to go" based on audience needs (i.e., as opposed to a linear set of slides).

Longer-Term Application of Content or Skills: Follow-Up Survey

In late January 2012, a follow-up survey was administered to all graduate students who participated in the workshop series to determine the longer-term impact of the workshops, such as how graduate students might have applied the content and/or skills. The response rate was 70% (51 of the total 73 workshop participants), and all were satisfied with assistance received in their workshop from COSEE facilitators. Ninety percent indicated that they would recommend the FGSC workshop to their peers or colleagues and also wanted more pedagogical training in their graduate programs. Fifty-two percent indicated the concept-mapping tools had been useful to them since the workshop, and the remainder indicated that they were "not sure," in some cases citing the short time elapsed since the event itself (e.g., four months for COSEE California).

Since the FGSC workshops, the most likely uses of concept mapping in graduate students' broader impacts or educational outreach endeavors were to "better organize thoughts" (63%; n = 48) and "provide a bigger picture or context" (54%; n = 48). These findings were supported by open-ended responses that indicated concept mapping helped some graduate students to both organize and place their research in a larger context. In terms of applying content or skills learned during the FGSC workshops to their scientific research, the most frequent uses of concept mapping were to "organize thinking about an existing research/dissertation topic" (56%; n = 48), "develop research/dissertation topic" (44%; n = 48), and "explain research to my colleagues and/or peers" (43%; n =48). Nearly all (92%; n = 47) of the graduate students indicated that they had already, or were planning to, add concept mapping to their tools for organizing their research.

CONCLUSIONS

Ocean scientists can look to effective educational practices such as concept mapping to present their research in ways that can be readily connected to learners' pre-existing knowledge and help facilitate new understanding. With such skills, researchers can better elucidate how science is relevant not only to larger Earth systems but also to people's lives and livelihoods. Written feedback collected during the FGSC workshops supports that ocean scientists increased their capacity to effectively communicate the "big picture" relevance of ocean sciences using concept maps. Post-workshop evaluation data support that the workshop model is also effective in helping scientists at various levels to achieve deeper understanding and skill in deconstructing relatively complex topics. Based on follow-up evaluation findings, the FGSC workshops achieved the ultimate goal of having graduate students apply workshop content and/or skills to their own educational outreach, teaching, and research purposes. A benefit of engaging in such well-designed professional development activities can stimulate creative and analytical spheres of thinking for all parties involved. Learning how to better represent and communicate complex science to nonscientists does not have to be the traditional, draining "one-way street," but can instead offer new perspectives on research while contributing to the scientific literacy of society.

The authors invite ocean scientists to contact them about implementing FGSC workshops at their institutions.

Graduate students collaborate with faculty-level scientists to create concept maps at the FGSC workshop held at the University of Southern California.

Graduate students present their final concept maps during FGSC workshops at the University of Southern California (left) and Scripps Institution of Oceanography (right).

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