COSEE

COMMUNITY MEETING ON A FUTURE VISION FOR COSEE & NSF OCEAN SCIENCES EDUCATION

Meeting Report

NOVEMBER 3-4, 2010

THE COMMUNITY MEETING STEERING COMMITTEE

Cheryl Peach, *Scripps Institution of Oceanography, UC San Diego (Chair)*

Phil Bell, *University of Washington*

Annette deCharon, *University of Maine*

Danny Edelson, *National Geographic Society*

Carroll Hood, *Raytheon*

Cathy Manduca, *Carleton College*

Janice McDonnell, *Rutgers University*

Don Reed, *San Jose State University*

Sarah Schoedinger, *NOAA*

Gail Scowcroft, *University of Rhode Island, COSEE CCO*

Brian Smith, *Rhode Island School of Design*

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Executive Summary

More than ten years ago, a diverse group of research scientists and science educators came together under the auspices of the National Science Foundation (NSF) Ocean Sciences Division (OCE) to discuss the need for a nationally-coordinated effort to enhance ocean sciences education. The outcome was a community recommendation for the creation of a national network of regionally distributed Centers for Ocean Sciences Education Excellence (COSEE) that would build on exemplary ocean sciences education already taking place and look for opportunities to catalyze and leverage collaborations between ocean sciences researchers and educators. After almost a decade, the COSEE Network has grown and matured and has had a demonstrable positive impact on the ocean sciences research and education enterprise. As COSEE approaches its decadal review, it is apparent that while the vision articulated in the original workshop remains relevant, the landscape for ocean sciences education has changed in response to changes in national priorities, new directions in ocean sciences research, advances in technology, progress in learning sciences research, and transformation of social and professional networking by information and communications technology. Recognizing that the NSF investment in ocean sciences education should reflect this changing landscape, the NSF-OCE sponsored a Community Meeting in November 2010 to garner broad community input into the most promising new directions for NSF ocean sciences education and a next generation COSEE.

The Community Meeting on a Future Vision for COSEE and NSF Ocean Sciences Education was held November 3-4, 2010, at the Ronald Reagan Building in Washington, DC. The meeting included 65 participants from a cross-section of the science and education communities, including members of the National COSEE Network, the ocean sciences research community, the learning sciences community, and those with expertise in cyberinfrastructure for research and education. The Community Meeting's two days of lively discussions produced a set of recommendations that have been synthesized into this meeting report. Provided herein is the participants' consensus opinion on the critical priorities for NSF's ocean sciences education initiatives during the next decade and the role that a next generation COSEE can play in meeting these priority areas. The meeting was focused on thinking broadly about the future of ocean sciences education in the context of the NSF ocean sciences research and education enterprise, and in particular, on establishing clear alignment with major NSF investments in climate change and sustainability, ocean observing, education/outreach applications of cyberinfrastructure, research on learning, and the development of a diverse workforce.

The participants were divided into working groups, and during the group's deliberations *five overarching themes* emerged that were common to all working group discussions: 1) integrating current ocean sciences research and discovery into education initiatives; 2) broadening the participation of underrepresented populations in ocean sciences; 3) integrating emerging technologies; 4) recognizing the formal-informal continuum in science education; and 5) embracing an inclusive, multidisciplinary, team-based approach to ocean sciences education. These crosscutting themes serve as common "threads" that tie together the *four key focus areas* that the meeting participants identified as the most promising future directions for NSF ocean sciences education:

Delivering Clear, Compelling Ocean Sciences Information to the Public

Society is grappling with a large number of pressing environmental and sustainability issues that are often poorly communicated to the public by the scientific community and miscommunicated by the popular media. Advances in social sciences and science communications research are providing new insight into crafting and delivering clear, compelling science messages to reach and impact targeted audiences. These strategies, when combined with recent trends in mass media and information and communications technology, can help the ocean sciences research and education community dramatically increase their capacity to reach a broad cross-section of society with key ocean sciences information. The community should embark on a state-of-the-art, research-based initiative to dramatically increase the number of people who perceive understanding the ocean to be essential and who use ocean sciences information to make informed decisions about important ocean related issues. Highlighted in the initiative should be the vast potential ocean sciences research holds for informing solutions to some of the grand challenges facing society (e.g. climate change, sustainability of ocean fisheries, biodiversity, sea level rise).

Using Ocean Data to Teach Scientific Thinking: Engaging Non-scientists in Ocean Sciences Research

Advances in computing, cyberinfrastructure, and information and communications technology are changing the way ocean sciences research is conducted. In a parallel trend, recent advances in web-based, inquiry-driven formal and informal education have led to development of on-line platforms for instruction that engage learners in active scientific inquiry, incorporate computer simulations of real-world phenomena, and involve collecting and analyzing data. In combination, these research and educational advances provide the basis for a more fully integrated ocean sciences research and education enterprise and provide an unprecedented opportunity to immerse learners in ocean discoveries. As observatory systems (e.g. NSF's Ocean Observatories Initiative (OOI) and Rolling Deck to Repositories (R2R) programs) and other ocean sciences data collection, analysis, visualization and archiving systems become increasingly pervasive and automated, these systems provide a context for readily addressing fundamental questions in research on cyberlearning. Moreover, the answers to these questions can be applied to create effective ocean sciences learning experiences that are firmly grounded in both learning sciences and the evolving paradigm for ocean sciences research.

Elevating Ocean Sciences to a Place of Prominence in the Educational Continuum

Ocean sciences is both a distinct topic of instructional focus, and a system of important concepts that must be integrated across the mainstream science curriculum. Historically, ocean sciences has been marginalized in both national and state science standards. The U.S. Commission on Ocean Policy reported that the absence of ocean sciences in schools resulted in a generation of Americans ignorant of the importance of the ocean, placing our economy, environment, and national security at risk. While COSEE has made considerable progress in raising the prominence of ocean sciences in K12 and informal science education, the renewed focus on the oceans and ocean stewardship heralded by the National Ocean Policy provides the ocean sciences research and education community with a new basis for asserting that oceans sciences must be taught broadly and well. *Ocean Literacy: The Essential Principles of Ocean Sciences* is a transformative consensus document that needs to be more fully and systemically integrated into the mainstream formal and informal science education standards, curriculum, and learning materials. The community can play a central role in this integration by facilitating access to up-to-date, inspiring ocean sciences content, data, and interfaces. One avenue for undertaking this integrative role would be to establish an NSF *Science of Learning Center for the Oceans* (SLC) dedicated to how people learn about complex, interconnected, abstract systems, and that uses ocean systems and related ocean sciences learning progressions as its primary focus.

Broadening Participation in Ocean Sciences: Increasing Diversity in the Ocean Sciences Research and Education Enterprise

All individuals should be able to participate in ocean sciences research, learn about ocean science topics, and consider a career in one of the many contemporary research fields in the ocean sciences. Ocean sciences education is working to remove barriers to participation in ocean sciences research endeavors and to provide meaningful learning experiences. A strategy for supporting these diversity goals is focused on a range of specific efforts at different points in the science, technology, engineering and mathematics (STEM) education system. The development of future ocean sciences education efforts should include an enhanced effort to develop culturally appropriate messages, a deeper understanding of audience needs and instructional approaches that orient to cultural and indigenous knowledge. These efforts should leverage new research from the learning sciences community to determine the most effective means for broadening participation. COSEE's next generation should continue seeking and promoting strategic partnerships with organizations and networks that serve groups that are underrepresented in ocean research (e.g., Society for Advancement of Chicanos and Native Americans in Science, SACNAS; ASLO Multicultural Program, Institute for Broadening Participation, IBP).

Future ocean sciences education initiatives should integrate elements of all four of these focus areas so that the ideas, strategies and crosscutting themes embodied in each work in concert toward the broader aim of a more ocean literate society. Clear, compelling information about the ocean will make ocean sciences more engaging and accessible, and will heighten awareness of the ocean's influence on human wellbeing. Framing ocean sciences data, tools and scientific research in relevant contexts will encourage greater integration of ocean sciences into K-16 and informal education, and will support broader participation in ocean sciences. Increasing understanding of the ocean and ocean sciences research can help drive a Nation-wide commitment to sustaining a healthy ocean environment and will support informed decision making about critical ocean issues. Building on a firm foundation, and equipped with the fresh set of ideas and strategies articulated in this report, the National COSEE Network and the broader ocean sciences community stand well positioned to advance ocean sciences education into the next decade.

I. Introduction and Context for the Meeting

The ocean sciences research and education community is at a crossroads. On July 19th, 2010 President Obama signed an executive order creating the National Ocean Council (NOC), a body charged with setting national priority objectives and providing direction for implementing the National Ocean Policy (NOP). The vision of the NOP is *"An America whose stewardship ensures that the ocean, our coasts, and the Great Lakes are healthy and resilient, safe and productive, and understood and treasured so as to promote the well-being, prosperity, and security of present and future generation".*

The creation of the NOC and the articulation of the NOP vision underscore the critical need for advancing ocean sciences education to benefit the Nation. Widespread public stewardship of the ocean can only be realized through appreciation, understanding and knowledge-based decision making on ocean issues. Now more than ever, it is imperative that the ocean sciences community take a leadership role in supporting the National Ocean Policy.

Over the last decade, the NSF's COSEE program has played a central role in broad public understanding of the oceans by bridging the gap between those that practice ocean sciences research and those that teach and communicate ocean sciences. National COSEE Network initiatives have resulted in nationally recognized ocean sciences education programs that have united researchers and educators in developing the national Ocean Literacy Essential Principles, creating new undergraduate and graduate courses in communicating ocean sciences, providing real and virtual experiences that engage people in ocean sciences research, developing tools for constructing new curricula, applying advances in learning sciences, and bringing new information and communications technologies to bear on ocean sciences education.

Yet the ocean sciences education landscape continues to evolve, including major advances in ocean sciences research, an explosion in information and communications technology, and the evolution of a robust cyberinfrastructure (CI) for research and education. Moreover, a host of new NSF ocean sciences and cross-directorate programs are emerging as critical efforts that support the NOP goals and the advancement of scientific knowledge about the ocean.

Key new NSF programs include:

The Ocean Observatories Initiative (OOI): The OOI is a large, new infrastructure program that promises to advance ocean sciences by allowing researchers to collaboratively observe and study the oceans on space and time scales not possible using traditional seagoing research methods. This networked infrastructure of sensor systems will measure the physical, chemical, geological and biological variables in the ocean and seafloor. Greater knowledge of these variables is vital for improved detection and forecasting of environmental changes and their effects on biodiversity, coastal ecosystems, and climate. Combining state-of-the art observing systems with a sophisticated CI, the OOI is designed to provide continuous, interactive, open access to ocean data and data products for ocean scientists, educators, and the public. Importantly, development of the educational CI for the project is taking place in parallel with development of scientific observatory components, ensuring that data and other resources will be accessible to non-scientist users. COSEE PIs, in collaboration with others in the ocean sciences education community, are key players in the OOI Education and Public Engagement program and are already designing the next generation of educational products that incorporate near real-time data, provide observatory-based social/professional networking capabilities for educators, and provide broad access to OOI data products and services for the public.

New oceanographic research vessels: Proposed additions to the oceanographic research fleet will offer expanded opportunities for education at sea through new communication capabilities and data sharing through the NSF-funded Rolling Deck to Repository (R2R) program. The R2R program envisions the academic fleet as an integrated global observing system with routine underway data and documentation flowing directly from research vessels to a central shore-side repository. Key institutional partners in the project are also lead institutional partners in COSEE (e.g. Scripps Institution of Oceanography; the Woods Hole Oceanographic Institution) and key personnel are currently working to collaborate on public accessibility of R2R data and data products. Many of the strategies developed by the OOI Education and Public Engagement (EPE) program can be applied to R2R. COSEE has a history of facilitating educator at sea programs and for spearheading efforts that connect classrooms and science centers with ships conducting oceanographic research. As capabilities expand and new research vessels come online, COSEE has the experience and the prototype programs that can inform the next generation of research vessel-based tools and programs for education.

Climate Research Investment: One of the major new cross-directorate initiatives is the NSF's Climate Research Investment (CRI) program launched in 2009. CRI is a Foundation-wide activity that supports production of new knowledge that can lead to a more sustainable planet. The program comprises five components: 1) Water Sustainability and Climate Change; 2) Ocean Acidification; 3) Climate Change Education Partnership; 4) Decadal and Regional Climate Prediction using Earth System Modeling; and 5) Dimensions of Biodiversity. These programs support innovative research and education that will advance the Nation's capacity to understand and predict changes in Earths natural and human dominated systems, to assess the vulnerability and resilience of these systems to change, to foster workforce development, and to improve scientific literacy in these areas. The oceans and atmosphere are inextricably linked in controlling Earth's climate, and ocean sciences is integral to each of these program components. COSEE personnel and institutional partners are deeply involved in several of these initiatives, particularly those with a strong focus on communication, education and workforce development. Future efforts within the community will focus on more widespread and deeper integration of ocean related topics into the educational initiatives associated with each of these program components and COSEE is well poised to contribute to these initiatives.

Science, Engineering and Education for Sustainability: Looking beyond the climate research agenda, NSF is also broadening its scope to include sustainability. Announced in 2010, the Science, Engineering and Education for Sustainability (SEES) program will enable research and education activities that will build the scientific foundation for decision capabilities and the technologies aimed at mitigating and adapting to environmental change. CRI will be folded into SEES, which will address many of the challenges of sustainability at the energy, economy and environment nexus. Sustainability is a central tenet of ocean stewardship, encompassing wide-ranging issues such as ocean fisheries, offshore oil exploration, marine biodiversity, ecosystem-based management of marine environments, marine coastal planning, marine pollution and sea level rise among others. Ocean education is a crucial component of any sustainability-based initiative. COSEE and the broader ocean sciences education community have a long and successful track record of bringing sustainability issues into the public forum and is developing innovative new approaches for creating interdisciplinary teams to address challenging communications issues.

Cyberinfrastructure Framework for the 21st Century (CF21): Recognizing that CI is changing how research and education are conducted, this new NSF initiative will foster the development of a comprehensive, secure, and sustainable CI that will support transformative research and education in science and engineering. Ocean sciences is a leading contributor to CI for research and education through the OOI and its sophisticated integrating CI, the largest investment in NSF's CI history. By including creation of educational CI in the construction process, the OOI stands to set a precedent for science education by 1) thoroughly integrating education into a major NSF research investment from the start; and 2) creating a model for educational CI for future foundation wide research investments. COSEE experience and expertise is proving central to the development of education-focused cyberinfrastructure for ocean sciences (i.e. OOI).

Science of Learning Centers: NSF *Science of Leaning Centers* are engaged in research to advance the frontiers of current understanding of how people learn. Ocean sciences education can make unique contributions in this research arena in areas such as increasing understanding of 3D and 4D spatial thinking skills, development of graphical interfaces and data visualizations for science teaching and learning, and teaching using observatory systems and other sensor networks. Distinct from many other science disciplines, ocean sciences experts depend not only on a wide range of analytical skills, but on temporal and spatial thinking skills that allow them to visualize and interpret complex environmental data collected over a range of scales. Recently recognized as important skills to foster in the Nation's next generation of innovators (NSB, 2010), spatial reasoning skills are emerging as an important new area of education research. Ocean science education has a unique contribution to make in this arena and is well positioned to do so.

These emerging programs within NSF offer a robust framework to support the NOP by advancing both ocean sciences as well as public appreciation, understanding, and stewardship of the oceans. The ocean sciences research and education community must continue to seek out and investigate effective mechanisms for fully integrating research and education within these programs and must expand the capacity to tap into and build on their infrastructure to ensure meaningful uses of the data, programs, and resources for ocean sciences teaching, learning, and discovery.

As a well-established NSF network with a strong foundation in the integration of research and education, a next generation COSEE has a leadership role to play in this effort. COSEE can bring the prodigious expertise, resources and infrastructure of the National COSEE Network to bear on spearheading new and innovative approaches, as well as facilitating broad, national and international scale partnerships that combine efforts with other networks of educators, communicators, learning scientists and researchers dedicated to public understanding and stewardship of the ocean.

II. Community Meeting Structure

The Community Meeting was planned by a steering committee comprising an equal number of COSEE Network members and representatives from outside of the Network. Meeting participants were sought that would represent a diverse body of expertise. The selected group included science researchers, four-year and community college educators, CI experts, learning scientists and K-12 and informal educators. Approximately half of the participants are active members of the National COSEE Network. Participants were charged with looking toward the future and identifying the most promising opportunities for transforming and catalyzing ocean sciences education and with recommending innovative strategies to capitalize on those opportunities.

Specific workshop objectives included:

- Exploring a future vision for the next decade of NSF ocean sciences education that builds on existing capabilities and strengths, while capitalizing on opportunities afforded by the rapidly advancing ocean sciences research and science education enterprise.
- Articulating a vision that emphasizes the NSF commitment to the integration of ocean sciences research and education, and to catalyzing and sustaining collaborations between ocean sciences researchers and science educators.
- Generating a set of far-reaching, strategic recommendations for key focus areas for the future of NSF ocean sciences education that build on the programs, network capabilities and infrastructure of the National COSEE Network, that take into account the emerging CI for research and education, and that will support integration of ocean sciences education into the NSF ocean research portfolio and the broader Foundation-wide initiatives.

An introductory address by Dr. David Conover, Director of the Ocean Sciences Division in the NSF Geosciences Directorate, set the overarching context for the meeting by articulating the NSF perspective on key considerations for the future of ocean sciences education at the Directorate. This introduction was followed by two plenary presentations emphasizing the growing understanding of effective practices in science communication (Dr. Ed Maibach) and the rapidly evolving role of technology in science education (Dr. Roy Pea). Synopses of the presentations are presented below.

ED MAIBACH

Effectively Educating the Public and Decision-Makers about the State of our Oceans: Five Guiding Principles

THE FORMULA FOR PUBLIC EDUCATION EFFECTIVENESS:

- *"Simple clear messages, repeated often, by a variety of trusted sources."*

FIVE GUIDING PRINCIPLES:

- *The less you say, the more you're heard.*
- *The decision about what to say requires audience research.*
- *There is no such thing as "the public."*
- *If failure (of the public education effort) is not an option, create a public education team.*
- *Clearly identify which personal actions, and which societal actions, are most important.*

SUMMARY:

- *To get your public education content right, create a multi-discipline education team and study your audience carefully*
- *To ensure that your content is received & learned, develop simple clear messages, repeated often, by a variety of trusted source.*
- *To maximize the odds that your public education will influence people's actions appropriately, clearly identify which personal actions, and which societal actions, are most important.*

ROY PEA

Cyberlearning frontiers for the convergence of ocean science and education with the learning sciences

"Integration of ocean science research and education" needs to be two-way. Not only a one-way flow from ocean science to teaching about the science, but an engagement of learners in the science, as in student-scientist partnership projects.

IMPORTANT INSIGHTS FROM LEARNING SCIENCES CAN INFORM OCEAN SCIENCES EDUCATION:

- *Designing to encompass formal and informal learning contexts and pathways*
- *Using new insights into "expertise" development (e.g. understanding the social aspects of the acquisition of expertise)*
- *Teaching scientific reasoning in the context of the science disciplines (e.g. using their tools, academic language, inquiry methodologies, norms)*
- *Designing using an iterative research, development and testing process that includes long term partnerships with educators, districts, broader communities*

SUMMARY:

- *Advances in the learning sciences give us valuable insights into how people learn.*
- *Technology innovations give us the ability to act on these insights as never before.*
- *Life-long, life-wide learning ecologies requires new designs.*
- *Leverage best practices today AND invent your own future of cyberlearning for ocean sciences and education*
- *Cyberlearning for ocean sciences should leverage high interest features of ocean science (e.g. mystery, natural hazards, sustainability and stewardship)*

Breakout discussions following the plenary presentations were focused on identifying a big picture vision for the future of ocean sciences education based on the following overarching questions:

How can contemporary, consensus perspectives on science learning and teaching (learning insights, design principles, theoretical perspectives) be leveraged to better integrate ocean sciences research and education, and advance ocean sciences literacy?

How can the capabilities of selected, relevant cyberinfrastructures and/or the concept of a virtual community be leveraged to further the goal of integrating ocean sciences research and education?

What approaches can be used to best support education and outreach at the leading edge of ocean sciences research?

In the overall science education landscape of the future, what is the optimal position for NSF-supported ocean sciences education?

Each broad topic area above served as the basis for discussion in the Day 1 breakout sessions. The morning session discussions focused on the broader vision and the afternoon session on specific implementation strategies. Working group participants were assigned to the groups based on their area of expertise and the steering committee's efforts to achieve an appropriate balance of experience within each group. Day 2 was dedicated to eliciting the high-level, compelling, bold ideas that emerged during the Day 1 discussions. A breakout session in the morning led to the development of a list of 22 "big ideas" for future directions in ocean sciences education. These ideas were subsequently synthesized into 4 recommendations for key focus areas and implementation strategies for the future of NSF ocean sciences education. An important and unplanned discussion that took place during the morning plenary session addressed the question "What constitutes transformative change?". This discourse contributed significantly to framing subsequent breakout group discussions of the key focus areas. Also identified over the course of Day 2 was a set of 5 crosscutting themes that figured prominently in all plenary and breakout group discussions. The detailed meeting agenda and participant list are in Appendix I.

This report is a synthesis of the most promising opportunities identified at the meeting. It includes recommendations for *key focus areas* for the future of NSF ocean sciences education that build on the programs, network capabilities and infrastructure of the National COSEE Network, that take into account the emerging cyberinfrastructure for research and education, and that will support integration of ocean sciences education into the NSF ocean research portfolio and the broader Foundation-wide initiatives. It defines objectives for transformative change in ocean sciences education (Section III) and articulates key focus areas, suggested implementation strategies, and crosscutting themes that should figure prominently in future NSF ocean sciences education planning (Section IV).

III. Transforming Ocean Sciences Education
What will future success look like?

Effective practice in strategic planning and in educational design both emphasize the importance of articulating a desired end state and potential pathways to that end state. The National COSEE Network has executed this exceptionally well through strategic planning efforts that are goal and outcome oriented and that are examined and reevaluated regularly. The net result has been increased community capacity to effectively integrate research and education, and a distinct cultural change in the ocean sciences research community such that education and outreach has become a normal part of conducting research for many ocean scientists. Ocean sciences meetings are now filled with education and outreach strands, science education and ocean sciences education meetings are re-invigorated and regularly focus on bringing cutting edge science into classrooms, and ocean sciences now is recognized in the mainstream science education reform movement when standards and instructional materials are being discussed.

Meeting participants recognized that as the community continues to move forward, future progress depends on an outcome-oriented approach in which both desired end states and pathways are defined. Participants were encouraged to think boldly about new opportunities and strategies for NSF ocean sciences education by considering what would constitute *transformation* in ocean sciences education from its current state, and to use these ideas as a context for the discussion of specific implementation strategies. It was broadly agreed that advancing ocean sciences education to the next level would require yet more change in the culture and capacity of the ocean sciences research and education enterprise including:

- A radically expanded (i.e. three orders of magnitude or more) audience for ocean sciences education achieved by integrating and coordinating outreach, informal and formal education strategies to reach people of all ages.
- Changed public attitudes and behaviors that reflect increased respect for the oceans, recognition of the value of the ocean to their lives and appreciation of the ocean sciences research enterprise.
- A more cohesive and systematic merging of ocean sciences research and education
- Efficient and well-defined pathways for integrating the latest science discoveries into ocean education programs
- A unified ocean sciences research and education community that is collectively responsive to trends across ocean sciences research, social networking and social media, information and communications technology, learning sciences and STEM education

Inspired by this conceptualization, subsequent discussions yielded four “key focus areas” for the coming decade of NSF ocean sciences, a set of cross-cutting themes that were common to all, and key implementation strategies for reaching focus area objectives.

IV. The Future of NSF Ocean Sciences Education

A. ALIGNMENT WITH NSF AND NATIONAL PRIORITIES

Throughout the Community Meeting plenary and working group discussions, it was widely recognized that any plan for the future of ocean sciences education must reflect and complement National level policy and principals for STEM education and public understanding of science. The groups' recommendations are thus well aligned with the guiding principles for NSF's STEM efforts, with the Geosciences Directorate Education and Diversity 2010-2015 Strategic plan, and with the National Ocean Policy (NOP, 2010). This outcome reflects the community's recognition of the importance of integrating STEM education, outreach, and communications across NSF's portfolio of activities, while leveraging NSF's investments in scientific research.

> The National Science Board stated that the NSF STEM education road map and strategic priorities should reflect the Foundation's responsibilities to:
>
> - *Support research on learning and educational practices and the development of instructional materials.*
> - *Develop human capital (e.g. STEM workforce development).*
> - *Increase public appreciation for and understanding of science, technology, engineering, and mathematics.*
>
> *National Action Plan for Addressing the Critical Needs of the U.S. Science, Technology, Engineering and Mathematics Education System* (National Science Board, October 2007).
>
> The Geosciences Directorate 2010-2015 Strategic Plan has as its overarching goals:
>
> - *Advancing public literacy in Earth system science*
> - *Preparing the geoscience workforce of the future*
>
> The National Ocean Research Policy has two of its core objectives
>
> - *Foster a public understanding of the value of the ocean, our coasts, and the Great Lakes to build a foundation for improved stewardship (National Policy in: Final Recommendations of the Interagency Ocean Policy Task Force, 2010).*
> - *Better educate the public through formal and informal programs about the ocean, our coasts, and the Great Lakes (National Priority Objectives in: Final Recommendations of the Interagency Ocean Policy Task Force, 2010).*

Community Meeting recommendations align with the principles from each of these plans in that they focus on combining ocean sciences with learning and communications sciences to promote: 1) public understanding of ocean sciences and cultivation of ocean stewardship; 2) leveraging advances in ocean sciences research and cyberinfrastructure to enhance STEM learning of 21 st century science and technology skills; and 3) broadening participation in ocean sciences to expand the talent pool for the 21 st century workforce.

The crosscutting themes and key focus areas that emerged from the meeting discussions are described in detail below, along with specific implementation strategies that can be used in NSF ocean sciences and the next generation of COSEE.

B. CROSSCUTTING THEMES

Over the course of the Community Meeting, five overarching themes emerged as common to all of the discussions: 1) integrating current ocean sciences research and discovery into education initiatives; 2) broadening the participation of underrepresented populations in ocean sciences; 3) integrating emerging technologies; 4) recognizing the formal-informal continuum in science education; and 5) embracing an inclusive team-based approach. These themes constitute the "threads" that tie the key focus areas for the future of NSF ocean sciences education together and are an essential element of the participants' recommendations to the NSF.

1) Integrating current ocean sciences research and discovery into education initiatives

Emerging programs within the NSF offer unprecedented opportunities to integrate ocean sciences research and education in ways previously unimaginable. The last decade has seen an explosion in connectivity enabled by the Internet, as well as a pro-

found cultural change in the way researchers, students, teachers, and the public access information, collaborate professionally, and interact socially. These changes demand a concurrent evolution of the approaches used to establish partnerships in education around NSF science and of the strategies used to communicate ocean sciences to public audiences. Online scientific collaboration is rapidly becoming the norm and holds great promise for facilitating interactions between researchers and non-scientists across the formal-informal education continuum, including interactions from remote field sites and research vessels. New learning sciences research on using scientific data and visualizations in a variety of learning contexts is creating the basis for integrating authentic ocean sciences data from programs like R2R and OOI into classroom activities, citizen science projects, and science center exhibit elements. As NSF broadens its scope to include sustainability through SEES (and CRI), the community can capitalize on public interest and engagement in these highly relevant topics to devise ways to communicate how the ocean sciences research enterprise contributes to helping the nation meet grand challenges to society. Finally, Science of Learning Centers are paving the way for in-depth research into how to promote student learning in areas uniquely emphasized in ocean sciences such as spatial reasoning skills.

COSEE has had a significant role in the development of education programs associated with many of these initiatives and has been actively addressing many of the challenges presented by the rapidly evolving technology for research and education. A next generation COSEE is poised to provide both leadership and insight into effectively integrating research and education in large science and science infrastructure projects in this continuously evolving landscape.

2) Broadening the participation of underrepresented populations in ocean sciences

Although this theme was the focus for an individual working group, all groups felt that it deserved central consideration. With less than 6% of the ocean sciences work force comprising individuals from minority populations, it is imperative that ocean sciences education efforts continue to strive to reach the broadest audience possible. Access to ocean sciences learning experiences must be developed across the formal and informal science education spectrum. In addition, there is a critical need to increase the number of people who view ocean stewardship to be in their self-interest. The development of future ocean sciences education efforts should include an enhanced effort to develop culturally appropriate messages, a deeper understanding of audience needs and instructional approaches that orient to cultural and indigenous knowledge. These efforts should leverage new research from the learning sciences community to determine the most effective means for broadening participation. Emerging ocean observation technology may provide a gateway for reaching vast audiences. However, access by urban and rural youth must be considered when developing the delivery systems.

To reach broader audiences, non-traditional venues should continue to be explored and expanded for implementing ocean sciences education experiences (e.g. Boys and Girls Clubs of America, Girl Scouts, 4-H). Although formal and informal learning are part of an educational continuum, focusing on the out of school end of the continuum will promote large scale dissemination and applicability of ocean sciences to geographically, economically, racially, and linguistically diverse populations. Future ocean sciences education initiatives can build on COSEE's expertise and experience in how to reach underserved and under represented audiences (e.g. COSEE personnel who specialize in research on learning and COSEE Centers that focus on underserved audiences).

3) Recognizing the formal-informal continuum in science education

Most life long learning takes place outside of formal K-12 classrooms (Banks et al., 2007; Bell et al., 2009). COSEE must continue its push to integrate ocean sciences into formal classroom curriculum as supported by national science education standards, and non-school opportunities for learning need to be developed that explicitly enhance and connect to the formal education experience. Learning sciences research on bridging the gap between formal and informal science education should be more intentionally integrated into ocean sciences education efforts, particularly as it applies to out of school learning contexts, and creation of a comprehensive formal-informal ocean sciences learning pathway. In addition to K-12 educators, informal science educators need professional development to stay abreast of the rapid advances in ocean sciences research and to become familiar with the use of emerging technologies.

The emergence of the "free-agent" learner, a new kind of student who is less dependent upon traditional education institutions and more self-reliant in driving their own educational destiny, is beginning to reshape education and to drive the demand for technology-enabled learning both inside and outside of the classroom (Project Tomorrow, 2010). Opportunities for *ocean cyberlearning* need to be situated in the context of growing realizations of the importance of learning outside of school and new technologies that can provide linkages between the formal and informal learning sectors should be exploited.

4) Integrating emerging technologies

As technological advances in computing, cyberinfrastructure, and communications revolutionize both science research and science education, ocean scientists and educators are beginning to capitalize on these advances to engage learners more directly in ocean discovery. Network-capable computing devices are increasingly pervasive, increasingly capable and increasingly mobile. Advances in cloud computing are changing how people use the Internet and as a consequence where and how they learn (Horizon Report, 2010). Users can now access computational resources, web services, software, and storage no matter where they are or what device they choose to use. Coupled with increasingly open scientific data and resources, and more accessible open platforms for developing learning and educational tools, these trends are beginning to transform science education and are figuring prominently in the ocean sciences communities planning for future ocean education initiatives. Rapidly evolving ocean observing programs equipped with sophisticated, integrated cyberinfrastructure will allow for millions of people to *experience* the ocean in new ways. These programs and their products have great potential to be integrated throughout the formal to informal science education spectrum and across multiple platforms including handheld mobile devices, classroom and personal computers, internet-connected multimedia displays in informal science institutions, and gaming platforms, among others. Global Positioning System (GPS) equipped mobile technologies are particularly promising as teaching tools and can provide local context for ocean observations as well as simultaneous access to and interactivity with ocean data, imagery, and visualizations.

The explosion of participatory media (blogs, wikis, social networking, music-photo-video sharing, podcasts etc.) is blurring the boundaries between content providers and their audiences. This evolving online culture and continuing advances in information and communications technology hold promise for "harnessing the collective intelligence" and for a "digital commons". All of these trends and technologies are becoming increasingly important in reaching broader audiences as learners search for opportunities that allow for interest-driven learning.

As new ocean sciences initiatives emerge, many of COSEE's existing strategic goals are being enhanced and expanded by tapping into emerging infrastructures for scientific research and education, and by capitalizing on the rapidly evolving Internet culture. Over the next decade, ocean sciences education will have the opportunity to engage the public as active participants in the research enterprise through emerging information and communication technologies, including social media and online platforms that allow interaction with data, visualizations, remote and virtual laboratories, and science and technology experts.

5) Embracing an inclusive, team-based approach to ocean sciences education

Ocean sciences education plays a critical role in addressing grand challenges affecting humanity and the planet. Just as ocean sciences research is by its nature a multi-disciplinary enterprise that requires teams of people with diverse expertise and skills, so to does ocean sciences education. The needs of the audiences should inform the composition and purpose of a multi-disciplinary ocean science education team and its composition should be related to the context of the ocean science education and communication effort. To accomplish this, knowledge from the learning sciences community about how people learn should be used to determine modes of communication, misconceptions commonly held by target audiences should be identified, and active participation in the ocean sciences enterprise should be invited. This team-based approach will ensure that advances in ocean sciences, technology, and learning sciences intersect for the benefit of a wide and diverse audience. For example, embracing cyberlearning for ocean sciences requires collaboration across learning sciences, information and communications technology (ICT), educational software development, ocean sciences, and formal and informal education.

C) KEY FOCUS AREAS

Community Meeting participants were asked to generate a set of far-reaching, strategic recommendations for key focus areas for the future of NSF ocean sciences education. Below is a synthesis of these recommendations and strategies for implementation that came out of the two days of discussion. The recommendations and strategies reflect the charge to the participants to build on the programs, network capabilities and infrastructure of the National COSEE Network, to take into account the emerging CI for research and education, and to support integration of ocean sciences education into the NSF ocean sciences research portfolio and the broader Foundation-wide initiatives.

Delivering Clear, Compelling Ocean Sciences Information to the Public

"Simple clear messages, repeated often, by a variety of trusted sources." Ed Maibach

Society is grappling with a large number of pressing environmental and sustainability issues that are often poorly communicated to the public by the scientific community and miscommunicated by the popular media. Advances in social sciences and science communications research are providing new insight into crafting and delivering clear, compelling science messages to reach and impact targeted audiences. These strategies, when combined with recent trends in mass media and information and communications technology, can dramatically increase the ocean sciences research and education community's capacity to promote ocean literacy across a broad cross-section of society.

The community should embark on a state-of-the-art, research-based initiative to dramatically increase the number of people who perceive ocean literacy to be essential and who use ocean sciences information to make informed decisions about important ocean related issues. Highlighted in the initiative should be the vast potential ocean sciences research holds for informing solutions to some of the grand challenges facing society (e.g. climate change, sustainability of ocean fisheries, biodiversity, sea level rise). The outreach initiative should be led by a team(s) comprising a wide spectrum of experts from diverse fields (e.g. ocean sciences; communications sciences; social sciences; ocean education; multimedia and new media; etc.). Working closely with ocean science researchers, these experts can help draw clear linkages between science and society, and illustrate how the scientific enterprise is relevant to people's everyday lives. The ocean environment itself provides an exciting context for conveying this information – filled with beauty and mystery, largely unexplored, inhabited by creatures from the charismatic to the bizarre, and an endless source of stories about human connections to and dependence on the ocean. Complex science can be deconstructed into a small number of simple and flexible messages to be used by people both internal and external to the science community. Ocean sciences information can be tailored to be culturally relevant to groups who traditionally do not have strong connections to the ocean. The initiative should take advantage of both traditional mass media outlets and emerging communications devices (e.g., mobile devices) and networks (e.g., Facebook).

To impact the attitudes, understanding and actions of large segments of the population, the ocean sciences community must work on the scale of a unified, integrated, national-international effort that is organized and sustainable for the long term. The COSEE Network can be central to this process by 1) tapping into existing COSEE Network infrastructure and national and international partnerships; 2) capitalizing on COSEE expertise in deconstructing complex science using tools such as concept mapping; and 3) leveraging the COSEE knowledge base on crafting culturally relevant ocean sciences messages.

Key Strategies for Implementation:

- Develop multi-disciplinary ocean sciences communications teams dedicated to deconstructing complex ocean sciences concepts and to creating and communicating a few simple, clear ocean sciences messages to targeted audiences. In addition to ocean scientists and educators, communications experts (e.g. social scientists specializing in science communication) should be integral to the teams so that information is framed and communicated effectively.
- Identify and pro-actively train and support a generation of charismatic ocean scientists who can effectively deliver ocean sciences knowledge and stories. Build communications programs around them and the key messages they specialize in delivering.
- To reach the younger generation, strategically partner with mass media outlets (e.g. engage producers of Sesame Street) to disseminate key messages. Use a variety of communications platforms (e.g. mobile communication platforms) to reach these audiences.
- Redefine the COSEE education position at the Smithsonian Sant Ocean Hall to better integrate NSF ocean sciences research and education initiatives with the exhibits, activities, and programs.

Using Ocean Data to Teach Scientific Thinking: Engaging Non-scientists in Ocean Sciences Research

Science, mathematics, and engineering education could be profoundly transformed by placing far greater emphasis on learning that is based on student interactions with complex data and systems (in Report on the NSF Taskforce on Cyberlearning, 2008).

Advances in computing, cyberinfrastructure, and information and communications technology are changing the way ocean sciences research is conducted. As the emphasis shifts toward multi-scale, long-term observation of the ocean, ocean sciences is becoming a discipline that is increasingly characterized by fast, seamless, open access to data; the ability to integrate diverse data resources generated through field observations and quantitative modeling; and (soon) the capacity to collaborate in real-time with geographically dispersed colleagues on observatory-based

science missions. In a parallel trend, recent advances in web-based, inquiry-driven formal and informal education have led to development of on-line platforms for instruction that engage learners in active scientific inquiry, incorporate computer simulations of real-world phenomena, and involve collecting and analyzing data. In combination, these research and educational advances provide the basis for a more fully integrated ocean sciences research and education enterprise and provide an unprecedented opportunity to immerse learners in ocean discoveries. The community should capitalize on these trends to provide learners with new and engaging ways to participate in ocean sciences research activities and to interpret and personalize their connection to the ocean.

As observatory systems (e.g. OOI; R2R) and other ocean sciences data collection, analysis, visualization and archiving systems become increasingly pervasive and automated, these systems provide a context for readily addressing fundamental questions in research on cyberlearning. Moreover, the answers to these questions can be applied to create effective ocean sciences learning experiences that are firmly grounded in both learning sciences and the evolving paradigm for ocean sciences research. Fundamental learning science research questions posed in the report of the NSF Task Force on Cyberlearning include:

1. How can STEM instruction incorporate authentic and realistic data from research, models, simulations, and other sources to improve lifelong science learning?
2. What forms of user interfaces and interoperable resources will allow students to easily experiment with resources such as simulation models and datasets established by and for science experts?
3. What are the benefits for science learning of new data visualizations, immersive environments, modeling environments, sensor networks, and other technologies?
4. What are the general principles that can guide adaptation of computational resources to different education and learning settings?

(from *Report on the NSF Taskforce on Cyberlearning, 2008*)

The ocean sciences research and education community should create an ocean sciences cyberlearning initiative that capitalizes on the exciting context of the ocean to investigate how science data can be incorporated into STEM instruction to improve life-long science learning. Success will require highly interdisciplinary research teams comprising ocean scientists and modelers, learning scientists, educational software developers, ocean education experts (formal/non-formal), experts on learning with sensor networks, data visualization experts and teachers. The knowledge gained will be applied broadly as the Nation advances its efforts in global observing and on training the 21 st century workforce.

Promising potential projects include: 1) Incorporating data and data products such as video, visualizations, and scientific models into virtual research environments for education. Audio, video, and data feeds will stream to multiple platforms that allow users to manipulate the feeds with software tools designed for exploration or authentic scientific inquiry. Advances in the semantic web will allow developers to capture various users' stories on how these ocean research data make meaning to them; 2) Developing "serious games" focused on research scenarios that support authentic inquiry by students. Multiplayer games can involve teamwork with a mission-like atmosphere where learners can manipulate information (e.g. data, video, images, models, observations) to create their own knowledge; and 3) Designing citizen science and/or crowd sourcing activities that will benefit both researchers and learners. These education activities could utilize thin clients (e.g. a droid or smartphone application) for exploration, collaboration and reporting. Use of thin clients will enable broader access by meeting learners "where they are".

A next generation COSEE will play a leadership role in defining the protocols and effective practices for bringing real-time science and action to the classroom and other learning environments. These practices can be readily shared online with others and help the community better understand and adapt to how various audiences connect with ocean science.

Key Strategies for Implementation:

- Create opportunities for direct learner involvement in ocean sciences afforded by large investments in ocean research cyberinfrastructure (e.g. OOI, R2R) and advances in cyberlearning by creating a new ocean cyberlearning initiative. The initiative would promote creation of cross-disciplinary communities of cyberlearning researchers and practitioners, including software developers and IT staff, educators at all levels, domain scientists, and social scientists - and would

equip them for carrying forward cyberlearning effectively in new ocean cyberlearning programs at both the college and pre-college level.

- Bring real-time science and action to the classroom and other learning environments by creating online collaborative environments that serve as virtual spaces for linking researchers, educators, and learners of all ages for research, education, and outreach. Data streams, photos and videos, and personal stories comprise the catalytic conversations that can take place in this environment. Social media, live video links, and asynchronous interactions (e.g. Facebook, YouTube, Twitter, etc.) can bridge multiple learning environments and technologies.
- Partner with entities that specialize in 3D visual representation of geographical information (e.g. Google Ocean, Fledermaus) to reach a broader audience and to give access to place-based learning opportunities. These tools are not yet fully tapped for use in ocean sciences education, but have potential to support novel learning opportunities that connect users to the ocean.

Elevating Ocean Sciences to a Place of Prominence in the Educational Continuum

Ocean sciences is both a distinct topic of instructional focus, and a system of important concepts that must be integrated across the mainstream science curriculum. Historically, ocean sciences has been marginalized in both national and state science standards. The U.S. Commission on Ocean Policy reported that the absence of ocean sciences in schools resulted in a generation of Americans ignorant of the importance of the ocean, placing our economy, environment and national security at risk. While COSEE has made considerable progress in raising the prominence of ocean sciences in K-12 and informal education, the renewed focus on the oceans and ocean stewardship heralded by the National Ocean Policy provides the ocean sciences research and education community with a new basis for asserting that oceans sciences must be taught broadly and well.

The ocean sciences research and education community should play a leadership role in elevating ocean sciences to a place of prominence in the education system that is comparable to its prominence and importance in the scientific community. Vetted by scientists and educators nationwide, *Ocean Literacy: The Essential Principles of Ocean Sciences* is a transformative consensus document that needs to be fully and systemically integrated into mainstream formal science education standards, curriculum, and learning materials. The community can play a central role in this integration by facilitating access to up-to-date, inspiring ocean sciences content, data and interfaces. The challenge is to transform the existing educational systems and services to incorporate accurate and compelling ocean sciences content and practices.

To provide leadership in formulating science education policy and professional development, the ocean sciences education community must engage in a unified approach that involves a combination of educators, ocean sciences researchers, and learning sciences specialists. One avenue for undertaking this leadership role would be to establish an NSF *Science of Learning Center for the OCEAN (SLCO)* dedicated to how people learn about complex, interconnected, abstract systems, and that uses ocean systems and related ocean sciences learning progressions as its primary focus. Ocean sciences research depends heavily on the visual—including 4-Dimensional—representation of data and models; interpreting these requires specific training and skills. Targeted ocean sciences educational research at an ocean-themed SLC could be used to address several challenges in coordinating learning across the matrix of formal and informal learning: 1) developing and maintaining flexible and dynamic curricular standards that address basic ocean sciences topics, and current and emerging ocean sciences research; 2) identifying learning progressions that address requisite skills for success in studying ocean sciences concepts (e.g. spatial reasoning); 3) linking those learning progressions to interpretation of real data, ongoing data collection and new discoveries; and 4) using information and communications technology to facilitate user-generated, value added content and engagement strategies (e.g. strategies that support creation of culturally relevant contexts for teaching ocean sciences) that make the content easier to share, discover, evaluate, and enhance.

Lifelong learning occurs within a matrix of formal and informal educational environments within which curricula and standards are developed and enacted. We see a transformative role for COSEE in supporting a broad community in creating compelling ocean sciences content and interfaces that can be used across formal and informal educational environments.

Key Strategies for Implementation:

- Create an ocean-themed Science of Learning Center that identifies and coordinates its work around an ocean-related grand challenge facing society. Turn that into learning progressions for a wide variety of audiences, tapping into ICT to disseminate and get feedback. A next generation COSEE could empirically document the discovered progressions and apply that knowledge in new situations and to other ocean challenges.
- Proactively ensure ocean science participation in development of National Common Core Science Standards. Actively pursue the inclusion of an ocean scientist(s) involved in K-12 education on the *Achieve* design team that writes the standards. Enter into this effort in partnership with geoscience and geography education communities.
- Develop capacity to teach the discovery process of ocean sciences using local interests and values and get away from ocean content only. Use ICT tools that enable broader participation and apply learning science research on place-based, culturally relevant learning to ocean sciences education programs.

Broadening Participation in Ocean Sciences: Increasing Diversity in the Ocean Sciences Research and Education Enterprise

All individuals should be able to participate in ocean sciences research, learn about ocean science topics, and consider a career in one of the many contemporary research fields in ocean sciences. Ocean sciences education should remove barriers to and support participation in ocean sciences research endeavors and provide meaningful learning experiences to support the multiple goals of promoting ocean literacy for all, college-readiness, and pathways into STEM occupations. There is no single career or learning pathway or pipeline through STEM education (NRC, 2007, 2010). Therefore, a coordinated strategy for supporting these diversity goals would focus on a range of specific efforts at different points in the STEM education system.

The ocean sciences community should promote seamless learning experiences at a broad scale—across formal and informal learning settings—to provide access to compelling ocean sciences learning experiences to students from underrepresented groups in elementary through secondary schools and at undergraduate institutions. This could involve developing mobile technology learning platforms that sustain learning pathways for all learners and allow for more equitable participation in ocean sciences research. Social science studies indicate deeper use of social media and mobile technologies exist within specific underrepresented groups and can be leveraged in the design process. These learning experiences should allow for interest-driven learning, connect students into science-rich learning networks, and highlight the cultural and personal relevance of ocean science topics to their local communities.

The community should also apply and contribute to the social science literatures that inform efforts to broaden participation in the ocean sciences in order to most productively shape the educational activities in ocean sciences education. Some highly relevant literatures do exist, however, new empirical research should be conducted where relevant research does not exist including understanding the barriers to participation (e.g., through audience research, survey research) and creating meaningful learning experiences that attend to the cultural specifics (e.g., design-based research).

A next generation COSEE should continue seeking and promoting strategic partnerships with organizations that serve groups that are underrepresented in ocean research (e.g., Society for Advancement of Chicanos and Native Americans in Science, SACNAS; ASLO Multicultural Program, Institute for Broadening Participation, IBP). A two-prong strategy would include communicating ocean sciences research and career opportunities to those diverse communities. Secondly, individuals interested in ocean science topics should be provided with ongoing support (e.g., advising, mentoring, recruitment, and networking) to help establish the pathways for these individuals as they enter into the ocean sciences research and education community.

Key Strategies for Implementation:

- Support the "multiple publics" (Leiserowitz et al., 2010) in participating more deeply in ocean sciences research. Leverage social networking and participatory media to enable broader participation. Use a variety of research methods (e.g. communications, social and decision making science) to determine which pathways will be the most durable.
- Support broader audiences by creating and testing customizable, open source ocean science learning and communication materials that can be adapted and refined for new audiences. Scale successful materials to larger communities. Build on COSEE's experience with underserved audiences, and with online resources that are tailored for specific audiences, to support development of these materials.

- Develop/discover pathways for broadening participation in OS—including physical entry points to these pathways (i.e. where does one go to connect with research experiences). Engage the students where they are (e.g., in their middle school classroom, after school programs, in their community centers, etc.) Establishing partnerships with community-based organizations and minority-serving institutions are important pathways to doing this.
- Build on the COSEE Network experience in and infrastructure for collaborating with other organizations and networks that focus on broadening participation.

VI. Conclusions

The last decade saw tremendous progress in the integration of ocean sciences research and education, driven in large part by the catalytic programs and activities of the National COSEE Network. At the same time, advances in cyberinfrastrucuture and information and communications technology initiated profound paradigm shifts in the ocean sciences research and science education enterprises. Moving forward, the ocean sciences research and education community has the potential to build on past progress and to capitalize on a broad array of promising new opportunities afforded by these advances. The Community Meeting on a Future Vision for COSEE and NSF Ocean Sciences Education brought together a group of highly accomplished professionals to engage in far ranging, forward looking discussions on the most promising new opportunities for ocean sciences education and on key strategies for capitalizing on those opportunities. Participants included ocean scientists, science educators, learning science specialists, K-12 and college level instructors, and experts in cyberinfrastrucuture and information and communications technology. The discourse was brisk, stimulating and productive, and led to the articulation of a set of key focus areas and unifying crosscutting themes that together constitute a framework for *the future of NSF ocean sciences education and a next generation COSEE*.

The overarching community vision for the future is an American public that is more cognizant of the relevance of the ocean to their daily lives, and that perceives informed decision making about ocean related issues to be essential to the health, well-being and economic security of the Nation. Central to this vision is a dramatic increase in the number of people who are ocean literate, accompanied by heightened public awareness of the critical role ocean sciences research plays in advancing understanding of the ocean. Achieving this vision will require a multifaceted approach.

Learners of all ages and from all cultural, ethnic, and racial backgrounds can be engaged in ocean research and discovery. New ocean research initiatives provide exciting contexts for promoting scientific thinking and for allowing learners to tap into cutting edge scientific infrastructure and online data resources. Ocean sciences can be elevated to a place of prominence in the education system that is comparable to its prominence and importance in the scientific community. It should be fully integrated into national science standards and curricula across all of the science disciplines, and ocean scientists and educators should play a prominent role in this process. Finally, the community should continue to strive to remove barriers to participation in ocean sciences research endeavors and should provide meaningful, culturally relevant, place-based learning experiences that promote ocean literacy for a much broader cross-section of the public.

These efforts should emphasize the integration of ocean sciences research and education, with a focus on new NSF ocean science initiatives and cross directorate programs. Emerging technologies should be embraced when designing new programs as they provide mechanisms to connect researchers, educators and the public in ways that appeal to the new generation of continuously connected, mobile learners. Highly interdisciplinary teams should constitute a new paradigm in ocean sciences education as the community explores a rich new set of collaborations with experts that can help bridge the gap between science and the public. New initiatives must be carefully designed to leverage the existing infrastructure and expertise of the National COSEE Network, while integrating advances in ocean sciences research and research on learning. They must build capacity not only to reach new and larger audiences, but also to continually adapt as the landscape for ocean sciences research and education continues to evolve.

The ocean sciences research and education community is truly at a crossroads. The National Ocean Policy is a mandate to advance ocean sciences and ocean sciences education to benefit the Nation. Equipped with a set of strategies for increasing public appreciation and understanding of the ocean and ocean sciences, the National COSEE Network in partnership with the broader ocean sciences community is poised to take a leadership role in achieving the NOP vision while increasing public engagement in and support for the ocean sciences research endeavor.

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Appendix 1: Community Meeting Participants

DIANE ADAMS
National Institutes of Health
adamsdi@mail.nih.gov

IVAR BABB
COSEE Technology and Engineering for Knowledge (TEK)
NURTEC, University of Connecticut
ivar.babb@uconn.edu

PHIL BELL
COSEE Ocean Learning Communities
University of Washington
pbell@u.washington.edu

BRIAN CAMPBELL
SAIC and NASA GSFC
Brian.A.Campbell@nasa.gov

BRUCE CARON
New Media Research Institute
bruce@tnms.org

BOB CHEN
COSEE Ocean Communities in Education And social Networking (OCEAN)
University of Massachusetts, Boston
bob.chen@umb.edu

SUE COOK
COSEE Florida: Water as Habitat
Ocean Research and Conservation Association
scook@teamorca.org

ANNETTE DeCHARON
COSEE Ocean Systems
University of Maine
annette.decharon@maine.edu

SEAN DUFFY
Fairfax County Public Schools
SDuffy@fcps.edu

LINDA DUGUAY
COSEE West
University of Southern California
duguay@usc.edu

DANNY EDELSON
National Geographic Education Foundation
dedelson@ngs.org

KATHY ELLINS
Institute for Geophysics
kellins@ig.utexas.edu

SARA ESPINOZA
COSEE National Advisory Committee
National Environmental Education Foundation
sara@neefusa.org

MICHAEL FEDER
National Research Council
Maf185@yahoo.com

AMY FLEISCHER
Massachusetts Audubon/Wellfleet Bay Wildlife Sanctuary
fleischer_amy@hotmail.com

ROSANNE FORTNER
COSEE Great Lakes
fortner.2@osu.edu

COREY GARZA
California State University Monterey Bay
cogarza@csumb.edu

MATTHEW GILLIGAN
Savannah State University
gilliganm@savannahstate.edu

ANDREA GINGRAS
COSEE Central Coordinating Office
University of Rhode Island
agingras@gso.uri.edu

SCOTT GLENN
COSEE Networked Ocean World
Rutgers University
glenn@marine.rutgers.edu

MICHELLE HALL
National Science Foundation
mihall@nsf.gov

ROSEMARY HICKEY-VARGAS
Florida International University
hickey@fiu.edu

JAN HODDER
COSEE Pacific Partnerships
Oregon Institute of Marine Biology, University of Oregon
jhodder@uoregon.edu

CARROLL HOOD
COSEE National Advisory Committee
Raytheon
cahood@raytheon.com

LIESL HOTALING
COSEE Networked Ocean World/CCO
lieslhotaling@yahoo.com

JULES JAFFE
Scripps Institution of Oceanography
jules@mpl.ucsd.edu

MAUREEN KAPLAN
NOAA
marlene.kaplan@noaa.gov

PAULA KEENER-CHAVIS
COSEE Ex-Officio
NOAA
Paula.Keener-Chavis@noaa.gov

RICK KEIL
COSEE Ocean Learning Communities
University of Washington
rickkeil@ocean.washington.edu

TOM KELLER
National Research Council, Board on Science Education
TKeller@nas.edu

KELLY KRYC
COSEE National Advisory Committee
Gordon and Betty Moore Foundation
Kelly.Kryc@moore.org

W. BRITT LEATHAM
California State University San Bernardino
bleatham@csusb.edu

JUDITH LEMUS
COSEE California
Hawaii Institute of Marine Biology
jlemus@hawaii.edu

ED MAIBACH
Center for Climate Change Communication, George Mason University
emaibach@gmu.edu

CATHY MANDUCA
Science Education Resource Center
cmanduca@carleton.edu

GEORGE MATSUMOTO
COSEE National Advisory Committee
Monterey Bay Aquarium Research Institute
mage@mbari.org

MIKE MAYHEW
COSEE CCO/Decadal Review
Synoptic LLC
michael.mayhew@comcast.net

MOLLY McCAMMON
COSEE Alaska
Alaska Ocean Observing System
mccammon@aoos.org

ANDREA McCURDY
Consortium for Ocean Leadership/OOI
amccurdy@oceanleadership.org

JANICE McDONNELL
COSEE Networked Ocean World
Rutgers University
mcdonnel@marine.rutgers.edu

JAMES MILLER
University of Rhode Island
Graduate School of Oceanography
miller@uri.edu

ELIZABETH MILL
American Meteorological Society
mills@ametsoc.org

LAURA MURRAY
COSEE Coastal Trends
UMCES Horn Point Lab
murray@hpl.umces.edu

ROY PEA
Stanford University
roypea@stanford.edu

CHERYL PEACH
COSEE California
Scripps Institution of Oceanography, UCSD
cpeach@ucsd.edu

ROMY PIZZICONI
COSEE Central Coordinating Office
University of Rhode Island
romy@gso.uri.edu

CHRIS QUINTANA
University of Michigan, School of Education
quintana@umich.edu

DONALD REED
San Jose State University
dreed@sjsu.edu

TED REPA
COSEE Ocean Systems
theodore.repa@touro.edu

ANNIE RICHARDSON
NASA/Jet Propulsion Laboratory
Annie.Richardson@jpl.nasa.gov

LISA ROM
National Science Foundation
elrom@nsf.gov

SHAWN ROWE
COSEE Pacific Partnerships
Oregon Sea Grant, Oregon State University
shawn.rowe@oregonstate.edu

CAROLYN SCHEURLE
Observatoire Oceanologique de Villefranche sur Mer
carolyn.scheurle@obs-vlfr.fr

SHARON SCHLEIGH
East Carolina University
schleighs@ecu.edu

SARAH SCHOEDINGER
COSEE Ex-Officio
NOAA
sarah.schoedinger@noaa.gov

MARK SCHRADER
Around The Americos
cmarkschrader@earthlink.net

THERESA SCHWERIN
Institute for Global Environmental Strategies
theresa_schwerin@strategies.org

GAIL SCOWCROFT
COSEE Central Coordinating Office
University of Rhode Island
gailscow@gso.uri.edu

BRIAN SMITH
Rhode Island School of Design
bsmith@risd.edu

LUNDIE SPENCE
COSEE SouthEast
South Carolina Sea Grant Consortium
lundie.spence@scseagrant.org

KRISTEN ST. JOHN
James Madison University
stjohnke@jmu.edu

MARK ST. JOHN
Inverness Research Inc.,
COSEE National Network Evaluation
Mstjohn@inverness-research.org

CRAIG STRANG
COSEE California
Lawrence Hall of Science, UC Berkely
cstrang@berkeley.edu

SHARON WALKER
COSEE Central Gulf of Mexico
Institute for Marine Mammal Studies
sharon@imms.org

LYNN WHITLEY
COSEE West
USC Wrigley Institute for Environmental Studies
lwhitley@usc.edu

EDIE WIDDER
COSEE Florida: Water as Habitat
Ocean Research and Conservation Association
ewidder@teamorca.org

ROBERT WOOLARD
ePals, Inc. / ZG Ventures
harbingerfellow@gmail.com

Appendix 2: Community Meeting Agenda

MEETING GOAL

To explore broadly a future vision for the next decade of NSF ocean sciences education that builds on existing capabilities and strengths, while capitalizing on opportunities afforded by the rapidly advancing ocean sciences research and science education enterprises. The vision must emphasize the NSF commitment to the integration of ocean sciences research and education, and to catalyzing and sustaining collaborations between ocean science researchers and science educators. The meeting outcomes will include a set of far-reaching, strategic recommendations for COSEE's role in achieving the vision that builds on the programs, Network capabilities, and infrastructure of the National COSEE Network; emerging cyberinfrastructure for research and education; and proven effective practices and programs of the larger ocean sciences and STEM education communities.

TUESDAY, NOVEMBER 2

Washington Marriott, Georgetown I

7:30-9:00 pm Community Meeting Introductory Gathering

WEDNESDAY, NOVEMBER 3

Ronald Reagan Building, Hemisphere A

8:30 am Breakfast *(Foyer)*

9:00 WELCOME: David Conover, Division Director, NSF Ocean Sciences

9:15 Introductions

9:45 PLENARY SPEAKER: *Edward Maibach, Director, Center for Climate Change Communication, George Mason University*

10:30 Break *(Foyer)*

10:45 PLENARY SPEAKER: *Roy Pea, Director, Center for Innovations in Learning, Stanford University*

11:30 Charge to the Community Meeting Attendees

11:45 DAY 1 WORKING GROUPS:

Group 1 (Continental C): How can contemporary, consensus perspectives on science learning and teaching be leveraged to better integrate ocean sciences research and education, and advance ocean sciences literacy?

Group 2 (Hemisphere B): How can the capabilities of selected, relevant cyberinfrastructures be leveraged to create or enhance a viable virtual organization to further the goal of integrating ocean sciences research and education?

Group 3 (Hemisphere A): What approaches can be used to best support education and outreach at the leading edge of ocean sciences research?

Group 4 (Meridian C): In the overall science education landscape of the future, what is the optimal position for NSF-supported ocean sciences education?

12:30 pm Lunch *(Foyer)*

1:30 CONTINUE WORKING GROUPS *(Hemisphere A, Hemisphere B, Continental C, Meridian C)*:

Output: 1-page draft summary response to vision questions (see Talking Points)

3:30 Break *(Foyer)*

3:45 CONTINUE WORKING GROUPS *(Hemisphere A, Hemisphere B, Continental C, Meridian C)*:

Output: Written document of implementation recommendations (see Talking Points) that can be shared among working groups

5:00 Adjourn

THURSDAY, NOVEMBER 4

Ronald Reagan Building

7:30 am Steering Committee Breakfast *(Hemisphere B)*

8:00 Breakfast *(Foyer)*

8:30 PLENARY: Reports from Day 1 and Discussion *(Hemisphere A)*

9:50 Break *(Foyer)*

10:00 SMALL GROUP DISCUSSION AND RECOMMENDATIONS *(Hemisphere A, Hemisphere B, Continental C, Meridian C):* In the context of the results from Day 1, identify an overarching vision, priorities and recommendations. Address the over arching questions.

Moving forward, what is our overall vision and strategy for making significant advances in the integration of ocean sciences research and education in the next decade? What are the highest priorities and key recommendations that will support achieving this vision?

11:00 Whole group report out and discussion *(Hemisphere A)*

12:00 pm Lunch and writing: Draft synthesis Vision and Recommendations document

1:30 SMALL GROUPS RECONVENE *(Hemisphere A, Hemisphere B, Continental C, Meridian C):* Comment on draft and identify outstanding issues

2:30 FINAL DISCUSSION *(Hemisphere A):* Edits of draft synthesis document; Next steps; Evaluation

3:30 Meeting adjourns

Appendix 3: Plenary Speaker Biographies

EDWARD MAIBACH, MPH, PHD

Ed Maibach is a professor of communication and director of the Center for Climate Change Communication at George Mason University. With over 25 years of experience as a researcher and practitioner of public health communication and social marketing, Ed now focuses exclusively on how to mobilize populations to adopt behaviors and support public policies that reduce greenhouse gas emissions and help communities adapt to the unavoidable consequences of climate change. Ed previously had the pleasure to serve as Associate Director of the National Cancer Institute, as Worldwide Director of Social Marketing at Porter Novelli, as Chairman of the Board for Kidsave International, and in academic positions at George Washington University and Emory University. He earned his doctoral degree at Stanford University and his MPH at San Diego State University.

ROY PEA, PHD

Roy Pea, D. Phil., Oxon. is David Jacks Professor of Education and the Learning Sciences at Stanford University, and Director of the Human Sciences and Technologies Advanced Research (H-STAR) Institute. He has published widely on research, development and theory concerning K-12 science and technology education fostered by advanced technologies. He served as President of the International Society for the Learning Sciences, is a Fellow of the National Academy of Education and the Association for Psychological Science, and co-founded Teachscape, a company providing K-12 teacher professional development with online communities using web-based video studies of standards-based teaching.