

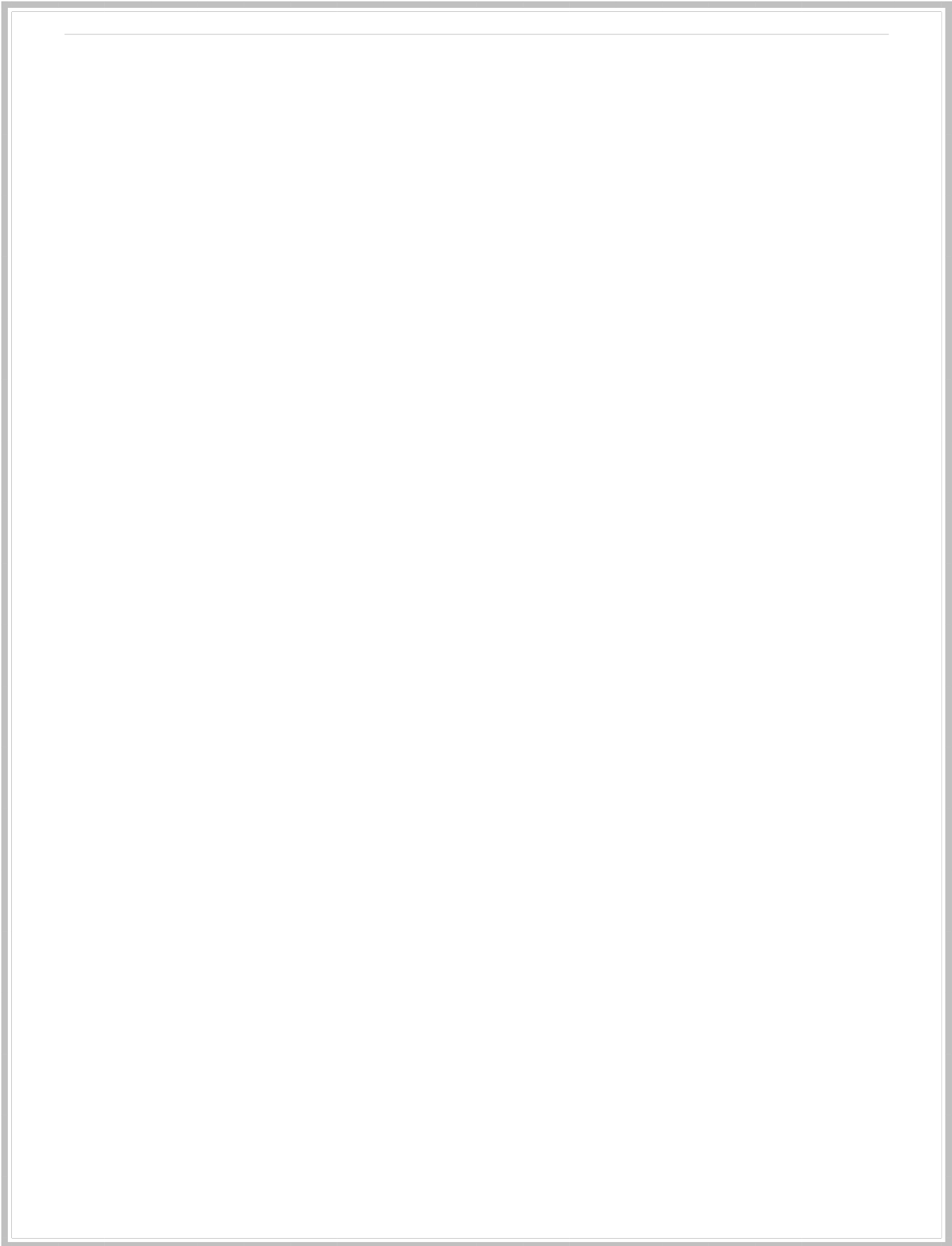
Leveraging Ocean Education Opportunities

A Report to the National Ocean Council



Ocean Research Advisory Panel

December 2013



Leveraging Ocean Education Opportunities

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1. Executive Summary

This report of the Ocean Research Advisory Panel (ORAP) responds to a National Ocean Council (NOC) request to *provide input on two key issues*:

- *Leveraging Federal ocean education efforts to maximize investments*
- *More effectively linking informal ocean education efforts to education standards*

The complete ORAP input for these can be found in Sections 8 and 9 of this report and are summarized below. Sections 3 through 7 of this report offer discussions, with examples of approaches and methods, for achieving:

- national ocean science education goals, target audiences, and measures of success;
- a transformation in ocean science education to foster enhanced ocean literacy;
- workforce development;
- ocean literacy in the general population; and
- best practices for interagency cooperation.

These discussion topics provide context for and suggestions on how to implement ORAP input and recommendations, which are summarized below and fully described in Section 10.

A number of key studies and reports have been published in recent years by the National Research Council that discuss Science, Technology, Engineering, and Mathematics (STEM) national education concerns and standards. In particular, the release in April 2013 of the *Next Generation Science Standards* (NGSS) offers concepts and a framework to make substantial progress in these areas. A significant difference between the new standards and previous national standards is the shift in formal science education curricula from lessons focused on content and one-way communication to an experiential approach, where the students are exposed to the *nature* of science and gain critical thinking skills as they interactively explore subject matter. The NGSS focus is on the practice of science or the “doing” of science. In our view, this is a substantial improvement and could be an excellent basis for linking formal curricula with informal science or “free choice” learning, particularly in an oceans context.

In the mid-1990s, a series of seminal reports ushered in a period of major reforms in science education. These reforms emphasized inquiry based learning over passive learning, integration of research and education, interconnecting themes over isolated content, technology-assisted learning, and standards-based curricula. Over the course of the last two decades, the most effective science education reform initiatives have integrated three essential areas of expertise, whether they occur in a formal or informal education setting.

These experts can be described as follows:

- The Educators (The Teacher, Museum/Aquarium Interpreter, Trainer, etc.);
- The Learning Scientists (The Cognition Experts); and
- The Scientists (Science Content Experts).

Simply stated, the *Educators* deliver content and provide learning experiences derived from and with the *Scientists*, as both are guided by the *Learning Scientists*. The learning scientists assist educators and scientists in understanding how people use their cognitive skills to acquire STEM literacy. This triumvirate of experts must work together to achieve the highest learning gains, for both formal and informal settings. This approach maximizes effectiveness of the learning event.

The U.S. Government Accountability Office (GAO) and Office of Science and Technology Policy (OSTP) completed separate inventories of STEM programs across the Federal Agencies in 2012. There is an appearance that coordination between agencies and between different programs within agencies – which often leads to similar short descriptions – may be considered duplicative, leading to the removal of programs that are actually complimentary. As part of the FY2014 budget submission, the Administration had proposed to increase the overall Federal investment in STEM programs (up 6.7% from FY12) while substantially reducing the number of programs – nearly halved – by combining or consolidating efforts or simply eliminating programs. The ORAP generally agrees with the notion of a Federal education portfolio that is effectively assembled, managed, and leveraged to meet national needs and goals. To develop such a portfolio, effective STEM programs should be retained, while others that lack evidence of effectiveness should be eliminated or charged to provide evidence of success. This Federal portfolio of programs should be assembled and managed using the three part synergistic basis described above to be effective and to be properly leveraged. This report offers a framework to develop such a portfolio, which will achieve these goals. The ORAP is concerned that the proposed consolidation of STEM education programs for FY 2014 will lead to further agency “stove piping” and a lack of national coordination and will impede the necessary three-part approach to education reform described above.

In early 2013, the President's Council of Advisors on Science and Technology (PCAST) released a report that forecasts a need for approximately 1 million more college graduates in STEM fields over the next decade than is expected under current assumptions. The economic growth of the U.S. is dependent on a STEM literate – ocean literate – workforce. An ocean literate workforce is required to fill positions in commerce, transportation, energy, food production, food safety, national security, and recreation/tourism. This workforce will support the country in addressing a wide range of challenges, including increased risks to coastal communities due to extreme events and the effects of climate change; safe and efficient maritime transport; and sustainable recovery of ocean-based energy resources, just to highlight several. The ORAP believes that STEM skills for jobs not requiring a four-year college degree and STEM literacy in the larger population are at least as important national concerns as the number of STEM college graduates and should be reflected in the Federal portfolio of education programs. The importance to our nation, and the Federal

Government in particular, of having a high-quality, highly relevant, flexible, expandable STEM-degreed and ocean literate workforce cannot be overstated. It is, of course, a critical element for all the NOC agencies.

All citizens should have the opportunity to become ocean science literate. Unless an individual seeks formal training in the ocean sciences or related subjects, opportunities to learn about the ocean are usually discreet and scattered. These opportunities are often also characterized as “Free-Choice Learning” which captures the voluntary, episodic, and varied means by which most individuals will gain knowledge about our oceans. These opportunities to learn may occur in the K-16 classroom, but are more likely to occur outside of formal schooling, where learning is not the primary activity. Thus, the discreet and scattered events may lack an overall framework to develop understanding or to enable a coherent view to be gained by the learner about the oceans and their processes. Fostering a framework to assist these individuals in building a more comprehensive and coherent understanding of the oceans provides a great opportunity for the NOC agencies to raise ocean literacy across the general population.

The NGSS offer a new and powerful tool for the NOC agencies to increase the use of coherent ocean science examples in K-12 STEM education by focusing on the published and tested Ocean Literacy Principles and Fundamental Concepts and how they are tied to the NGSS. Professional development for educators to these ends are encouraged and should introduce teachers to the online availability of real-time and predictive information from ocean data-driven programs for use in experiential elements of the NGSS. NOC agency sponsored workshops and educator professional development opportunities should be used to increase the availability and distribution of ocean science content material for the educators to use that is keyed to the NGSS outcomes. The engagement of other providers of ocean knowledge (television, filmmaking, magazines, museums, aquaria, etc.) in these programs will provide insights on how to link the activities of their “free choice learning” audiences to formal education activities, while providing professional development opportunities that deliver current ocean science content. Engagement by ocean scientists is critical, as noted in several recent studies, because the scientists not only can share current knowledge of the discipline, but can also effectively assist teachers in overcoming their hesitation to conduct learning activities that promote student understanding of the nature of science. This learning coherence can only be achieved through continuity and broad availability of programs at the local level. We note that the national goal of greater science literacy is also very well-served by greater ocean literacy given the natural interests in ocean issues among the general population.

Leveraging Investments to Maximize Educational Impacts – The key to leveraging efforts is to provide a common vision or conceptual framework, guidelines for interactions, and infrastructures for shared resources. The OSTP FY2014 proposed budget is a start in that direction, but the aim and approach must be made clearer, and the means to foster greater “triadic” collaboration across agencies and institutions, both public and private, needs to be developed. The new NGSS offers an educational approach and framework for this portfolio, while also offering a means to obtain maximum leverage. The specific program goals, target audiences, and measures of success must also be taken from a shared taxonomy. A culture of collaboration – based on regularly updated and published best

practices as described herein – must be created and rewarded. Efficient processes rather than cumbersome forums should be the norm. To these ends, leadership can minimize impediments that often lurk in the system. With the above in place, a national network that connects and supports the three transformative elements – Teachers – Facilitators – Scientists – must be funded so that each individual collaborator can readily add to the shared resources, while being able to draw more in-kind than provided. With such a network in place, all will feel that their investments are well-leveraged to the larger, national goal.

Effectively Linking Informal Ocean Education Activities to Education Standards –

The Next Generation Science Standards (NGSS) offer a unique and extraordinary opportunity to link formal and informal activities via programs and a Federal portfolio designed to do so. Since the NGSS are based on a more experiential approach to learning in order to foster individual reasoning and quantitative skills, opportunities to provide ocean-based materials to formal education curricula are clear, but equally important is an effort to shape “free choice” learning opportunities so they reinforce the formal curriculum experiences. To this end, NOC agencies can work together to increase an emphasis on ocean systems within the earth sciences component of the NGSS for the student experiences. This is perhaps the most effective way to introduce the generic STEM knowledge and skills because the natural sciences of the earth and oceans are of intrinsic interest to many learners. By coupling formal and informal experiences, the overall effort to improve STEM literacy can reach the entire population better than with any other STEM topic.

Summary of Key Recommendations

ENDORSE AND LEVERAGE NGSS: The National Ocean Council (NOC) should endorse the Next Generation Science Standards (NGSS) as the framework with which to align the NOC agencies’ education and outreach goals, both for formal and informal science education. The NOC agencies should offer ocean science experience and expertise as the cornerstone of the earth science component of the NGSS. To this end, NOC should invite the Department of Education, Council of State Science Supervisors, and the National Science Teachers Association to work with the NOC in the context of the NGSS. Lastly, the NOC should foster recognition that ocean science subject matter is a natural and socially -relevant means to improve overall U.S. STEM education via the NGSS.

FORM A ROBUST BASIS FOR THE FEDERAL STEM EDUCATION PORTFOLIO: The framework for assembling, managing, and leveraging a Federal STEM portfolio should be improved and made clearer to meet national needs and goals. The ORAP generally agrees with the notion of such a portfolio and offers a framework in this report to obtain the greatest impact and leverage. First, however, the balance between two aims must be established:

- a. The Federal Government increasing the formal STEM degree pipeline and
- b. Increasing the STEM literacy of the general population.

A STEM portfolio should be assembled and managed on the transformative “triadic” approach described in Section 3. Here is where the NOC agencies have a role that cannot be provided by others. Most NOC agencies reach from the Federal level to local institutions (e.g., labs, funded researchers, etc.) where the science content is developed and the education is delivered. Moreover, by connecting to the students and learners in a local, coherent manner, the parents of the children will also be entrained in a more coherent view of STEM methods and ocean literacy.

CREATE A NETWORK (of NETWORKS): The NOC should advocate for and support a national network that bridges many existing and dispersed networks and societies. The overall network (of networks) should achieve implementation of a mutual support system via access to databases of resource materials and professional development opportunities among Teachers – Learning Scientists – Ocean Scientists as basis for transformation of ocean education and STEM literacy. This network must have shared, measurable performance metrics that reflect the long-term nature of the clearer national goals.

UNDERSTAND AND OVERCOME THE IMPEDIMENTS TO BETTER PARTICIPATION IN THE OCEAN ENTERPRISE BY UNDER-REPRESENTED GROUPS, PARTICULARLY MINORITIES: Minority participation in STEM fields is generally low, but improving in recent decades. It is notable that little, if any, improvement can be seen in degrees and professions related to ocean science and the ocean industry. The reasons for this disparate outcome for ocean activities are not clear to ORAP. A better approach must be found, and a place to start is with a focused study of “lessons-learned” from both successful and less-so institutions and programs. We note that the mission agencies may be best situated to lead in this endeavor since they have a need to insure balance within their own workforces.

IMPROVE COLLABORATION ACROSS THE NOC AGENCIES AND WITH OTHERS: Interagency collaboration on common goals with clearly identified target audiences for each effort, and shared measures of success must be fostered and rewarded. In addition, agencies should develop, collect, and strongly foster “best practices” as we indicate in Section 7. To avoid budget impediments to this collaboration, OMB should consider assigning examiners as overseers to the key interagency collaboration plans and portfolios.

EXPLOIT “FREE CHOICE” INFORMAL LEARNING IN PARTNERSHIP WITH THE PRIVATE SECTOR, INCLUDING INDUSTRY: Using the NGSS framework and the above network of networks, engage television, filmmaking, magazines, museums, industry, aquariums, etc. in the development and representation of ocean science content with the support of ocean science experts. Make a strong statement for industry to be involved in this education and outreach effort. Many industries will employ increasing numbers of ocean STEM graduates, while simultaneously seeking support from the general public for their activities (offshore renewable energy, oil & gas production, aquaculture, transportation, etc.). The basis for a mutual partnership is clear. Bring in the major sectors at a very high level of governance to the network recommended above and encourage industry participation on a regional and/or sector basis with connections broadly at the local level.

FOSTER PROFESSIONAL DEVELOPMENT: ORAP recommends that Federal agencies support professional development programs for educators and ocean scientists, in general, and within their own ranks. The goal for professional development is to enable both formal and informal ocean science educators (teachers, journalists, docents, etc.) to become better educators and scientists to become better communicators. A certification program for informal educators in the ocean sciences (that incorporates the NGSS and Ocean Literacy Essential Principles) should be developed in conjunction with the ocean science community. This is an activity that the recommended network could implement. Similarly, this initiative should offer guidance to ocean scientists on how to more effectively contribute to education and outreach. In the end, the nation obtains maximum return by linking and enabling the triad of Teachers – Learning Scientists – Ocean Scientists to work together.

2. Introduction and Background

a. Tasking – The National Ocean Council (NOC), governing body for the National Ocean Policy (NOP), requested the Ocean Research Advisory Panel (ORAP) to undertake three main tasks for 2012-13. This report – approved by ORAP on 3 December, 2013 – responds to one of those tasks provided to ORAP as follows:

“Building on ORAP’s previous input and discussions on ocean education, provide input on:

- *Leveraging Federal ocean education efforts to maximize investments;*
- *More effectively linking informal ocean education efforts to education standards.”*

This task was accompanied by a NOC tasking overview:

“Every student in the Nation should encounter ocean sciences concepts in their K-12 educational experience, and the general public should have access to up-to-date information on the marine environment in informal settings. Federal agencies seek to improve ocean literacy through a variety of programs for students, educators, and the public using ocean-focused topics to teach STEM principles, increased public understanding of ocean and coastal science and the importance of the ocean in Earth systems is needed to foster a more informed citizenry, create better stewards of ocean, coastal, and Great Lakes resources; and increase awareness of opportunities related to these resources.”

The ORAP responses to the two specific task statements shown above can be found in Sections 8 and 9 of this report, which are titled accordingly. The earlier sections of this report (Sections 3-7) offer discussion of:

- national ocean science education goals, target audiences, and measures of success;
- a transformation in ocean science education to foster enhanced ocean literacy;
- workforce development;
- ocean literacy in the general population; and
- best practices for interagency cooperation.

These discussions set a context for our input to the NOC (Sections 8 and 9) and for our recommendations (Section 10).

b. Previous ORAP Efforts – In September 2002, the Ocean Research Advisory Panel of the National Oceanographic Partnership Program (NOPP) issued an outreach and education strategy aimed at improving ocean literacy and strengthening science education through an improved knowledge of the ocean, the Great Lakes, and our coasts. The development of the ORAP Education Strategy marked the first time that a comprehensive strategy for addressing ocean education issues had been targeted at such a high level across many Federal agencies.

The four goals of the 2002 ORAP Education Strategy were to:

- Foster outreach and public education involving ocean and coastal science;
- Use ocean science observing and information infrastructure to advance ocean literacy and science and technology education;
- Promote the development and diversity of the ocean-related workforce; and
- Formulate a policy and investment plan.

Much of the work done since then – such as the development of ocean literacy principles (2004-2005), the National Conference on Ocean Literacy (2006), the NOPP Strategic Plan, and the America COMPETES Act – has been in agreement with the major themes of the 2002 ORAP education and outreach strategy for ocean science education, and some progress has been significant. In July 2010, the ORAP approved an update to its Education Strategy, entitled *The ORRAP Education Strategy: Rethinking and Reinvigorating Interagency Ocean Education 2010-2020*¹.

c. Recent Key Activities and Publications – The National Research Council (NRC) has published a number of recent reports relevant to this subject. These include a revisit of the *Gathering Storm* report², the *Framework for K-12 Science Education*³, and the recent study on *Assuring the U.S. Department of Defense a Strong STEM Workforce*. The latter is focused upon the DOD STEM needs, but many of the issues and recommendations would apply to any other individual Federal agency in regard to its recruiting needs from the STEM pipeline in the U.S.⁴ The NRC *Framework* study has led to the development of the *Next Generation Science Standards* (NGSS)⁵ in a partnership between the NRC, the National Science Teachers Association (NSTA), the American Association for the Advancement of Science (AAAS), and Achieve, with 26 States preparing to be lead implementers. Following a national comment period on the draft standards, the NGSS were released on 9 April 2013. A significant difference between the new standards and previous national standards is the shift in formal science education curricula from lessons focused on content and one-way communication to an experiential approach, where the students are exposed to the *nature* of science and gain critical thinking skills as they interactively

¹ *ORAP Education Strategy White Paper*. http://www.nopp.org/wp-content/uploads/2010/03/ORRAP-Education-Strategy-white-paper_DRAFT_1-13-11.doc

² *Rising Above the Gathering Storm, Revisited*. Washington, DC: National Academies Press, 2010.

³ *National Science Education Standards*. Washington, DC: National Academies Press, 1996.

⁴ *Assuring the U.S. Department of Defense a Strong Science, Technology, Engineering, and Mathematics [STEM] Workforce*. Washington, DC: National Research Council, 2012.

⁵ *Next Generation Science Standards*. <http://www.nextgenscience.org/next-generation-science-standards>

explore subject matter. The NGSS focus is on the practice of science or the “doing” of science. In our view, this is a substantial improvement and could be an excellent basis for linking formal curricula with informal science or “free choice” learning, particularly in connection with an oceans context. This is described further in later Sections. The NGSS elements are briefly summarized in Appendix A. While a major advancement, these new standards will pose significant challenges to K-12 teachers, particularly regarding the teaching of earth and space sciences, in which few U.S. teachers have had training. The NOC agencies can assist in overcoming these challenges, as discussed in sections 8 and 9 below, as probably no others can.

The U.S. Government Accountability Office (GAO) and Office of Science and Technology Policy (OSTP) completed separate inventories of STEM programs across the Federal Agencies^{6,7} in early 2012. The GAO report did not reflect a uniform definition of a “STEM Program” and the results appeared to be a large collection of mostly uncoordinated efforts. The OSTP report delineated activities in a more uniform “program level” fashion and provided program details that differentiated the programs, but again, the level of interagency coordination was not evident, and the specific aims and achievements of individual programs were not clear. In our experience, this is not surprising, because agencies are often somewhat cautious about showing details and interagency linkages, particularly informal ones, in such calls for program descriptions and evaluations. As we will discuss later, in section 7b, this caution is well-founded. There is an apparent Office of Budget Management (OMB) interpretation that coordination between agencies and between different programs within agencies – which often leads to similar short descriptions – may be considered duplicative, leading to the removal of programs that are actually complimentary. The ORAP is concerned that the current proposed consolidation plan will lead to further agency “stove piping” and lack of coordination. Largely removing education programs from mission driven agencies where research is sponsored and conducted and then consolidating efforts under the U.S. Department of Education will isolate scientific research and its results from the education enterprise. By the same token, a number of local and regional programs are not fully reflected in those summaries, even if they are Federally funded in whole or in part.

In early 2013, the President's Council of Advisors on Science and Technology (PCAST) released a report⁸ that forecasts a need for approximately 1 million more college graduates in STEM fields over the next decade than is expected under current assumptions. PCAST argued that, “Merely increasing the retention of STEM majors from 40% to 50% would generate three-quarters of the targeted 1 million additional STEM degrees.” While this may be a valid forecast (although possibly optimistic⁹), the ORAP believes that STEM skills for jobs not requiring a four-year college degree and STEM literacy in the larger population are at least as important national concerns. A recent report by the OECD¹⁰ examines the

⁶*Science, Technology, Engineering, and Mathematics Education: Government-Wide Strategy Needed To Better Manage Overlapping Programs*. Washington, DC: GAO, 2012.

⁷*The Federal Science, Technology, Engineering, and Mathematics (STEM) Education Portfolio*. Washington, DC: OSTP, 2011

⁸*Engage To Excel: Producing One Million Additional College Graduates With Degrees In Science, Technology, Engineering, And Mathematics*. http://www.whitehouse.gov/sites/default/files/microsites/ostp/pcast-executive-report-final_2-13-12.pdf

⁹*STEM Crisis is a Myth*. IEEE Spectrum, 30 Aug 2013

¹⁰*OECD Skills Outlook: First Results From the Survey of Adult Skills*. OECD, 2013.

literacy and problem solving skills in the adult populations of 20 nations with advanced economies. Overall, the U.S. is ranked last, which may point to the bigger challenges. Further, a goal to simply increase retention in STEM undergraduate programs should be taken with reference to the “normal” attrition across all undergraduate fields as students find their way or not (estimated at about 33%). Reducing large excursions from normal attrition – as may be the case for underrepresented groups – should be a very worthy national goal, in our view.

There is, however, great potential for growth over the next several decades in careers that require ocean related education and knowledge. It is estimated today that 1 in 6 jobs in the U.S. are marine related¹¹ and growth in many existing maritime activities together with emerging ocean-based industries is likely to increase that share¹². Ocean science and engineering skills will also be critical as society grapples with sea level rise, tropical storms, and the need for new observing, forecasting, and mitigation technologies. As discussed above, literacy in these subjects amongst the general population will similarly become more critical.

The 2012 PCAST report proposed five overarching recommendations to transform undergraduate STEM education during the transition from high school to college and during the first two years of undergraduate STEM education:

1. Catalyze widespread adoption of empirically validated teaching practices.
2. Advocate and provide support for replacing “classic” laboratory courses with discovery-based research courses.
3. Launch a national experiment in postsecondary mathematics education to address the math preparation gap.
4. Encourage partnerships among stakeholders to diversify pathways to STEM careers.
5. Create a Presidential Council on STEM Education with leadership from the academic and business communities to provide strategic leadership for transformative and sustainable change in STEM undergraduate education.

These recommendations are congruent with the NGSS framework mentioned above, and, in fact, undergraduate student retention in STEM disciplines – the PCAST emphasis – depends on K-12 students being prepared for success in higher education STEM courses. The K-16 pipeline must therefore be viewed as continuous and is necessary to achieve national goals, where articulation across the elementary, secondary, and higher education continuum is critical. In addition, recent research on STEM learning has shown that the continuum between formal K-12 education and informal science learning activities must also be supported nationally, as discussed in the following sections.

¹¹ *State of the Coast: The Ocean Economy*. <http://oceanservice.noaa.gov/facts/oceaneconomy.html>

¹² *The Future of the Ocean Economy*. OECD, 2013. <http://www.oecd.org/futures/>

The recent release of the National Ocean Policy Implementation Plan contains two related objectives.

Under the topics of **Ocean Economy** and **Developing a Skilled Workforce**:

*“**Develop human capacity and the skilled workforce necessary to conduct ocean research and manage ocean resources.** Agencies will coordinate to ensure that educational programs include diverse student groups and that a highly competent workforce is developed. Agency actions will result in more students, particularly from underrepresented groups at the undergraduate and graduate level, pursuing academic fields related to ocean, coastal, and Great Lakes science and management. This will support the Nation’s leadership in ocean research and development and the application of best management practices. For example, agencies will use existing education and training resources to provide scholarship, fellowship, and internship opportunities that leverage existing Federal investments in ocean research, marine laboratories, and natural sciences to provide opportunities for education and training. Agencies will also contribute to periodic ocean-focused academic competitions for middle and high school students that have a positive impact on ocean-related career paths.”*

In view of the earlier discussion of NOC goals, the ORAP takes the above objective to encompass the entire U.S. ocean-related workforce – both public and private sectors – in the discussions to follow.

Under the topic of **Science and Information** related to **Our Understanding of Ocean and Coastal Systems**:

*“**Increase ocean and coastal literacy.** Increased public understanding of ocean and coastal science and the importance of the ocean in how our planet functions will empower people and communities to be better stewards of ocean resources and increase awareness of opportunities related to these resources. It will also increase interest in activities to address the issues facing the ocean, our coasts, and the Great Lakes. Agencies will contribute to opportunities for systematic inclusion of ocean topics and concepts into mainstream K-12 and informal education systems. Agencies will also develop content that incorporates the latest ocean science for use in schools, aquariums, science centers, National Parks, and other institutions, and conduct demonstration projects that deliver ocean observing data for schools and other educational opportunities.”*

As part of the FY2014 budget submission¹³, the Administration has proposed to increase the overall Federal investment in STEM programs (up 6.7% from FY12) while substantially reducing the number of programs – nearly halved, often by combining or consolidating efforts – and designating four priority areas for investment:

- K-12 instruction;
- Undergraduate education;

¹³ *Preparing a 21st Century Workforce.* <http://www.whitehouse.gov/administration/eop/ostp/rdbudgets>

- Graduate fellowships; and
- Informal education.

Throughout this ORAP report, we use the term “portfolio” to describe a defined collection of investments and programs managed together such as in the above proposed budget. Although this proposal may be “on hold” pending further Congressional review, the ORAP generally agrees with the notion of a portfolio that is effectively assembled, managed, and leveraged to meet national needs and goals. To develop such a portfolio, effective STEM programs (documented as such by evaluation) should be retained, while others that lack evidence of effectiveness should be eliminated or charged to provide evidence of success. This report offers a framework to assemble, manage and leverage such a portfolio to these ends.

3. A Transformative Approach to Foster Greater Learning

In the mid-1990s, a series of seminal national reports^{14,15,16} ushered in a period of major reforms in science education. These reforms, now familiar to educators at all levels, emphasized inquiry based learning over passive learning, integration of research and education, interconnecting themes over isolated content, technology-assisted learning, and standards-based curricula. As the reform movement gained traction, the ocean sciences community saw the multidisciplinary or integrative value of its subject area as an opportunity to support science education reform^{17,18}.

Over the course of the last two decades, the most effective science education reform initiatives have been fostered by integrating three essential areas of expertise, whether they occur in a formal or informal education setting. These experts can be described as follows:

- The Educators (The Teacher, Museum/Aquarium Interpreter, Trainer, etc.);
- The Learning Scientists (The Cognition Experts); and
- The Scientists (Science Content Experts).

Simply stated, the *Educators* deliver content and provide learning experiences derived from and with the *Scientists*, as both are guided by the *Learning Scientists*. The field of learning science emerged in the early 1990s to study learning as it happens in real-world situations and how to better facilitate learning in designed environments: in school, online, in informal environments, etc. The learning scientists assist educators and scientists in understanding how people use their cognitive skills to acquire STEM literacy. This triumvirate of experts must work together to achieve the highest learning gains, both in formal and informal

¹⁴ *Benchmarks for Science Literacy*. American Association for the Advancement of Science, 1993. Oxford University Press, New York.

¹⁵ *National Science Education Standards*. National Research Council, 1996a. National Academy Press, Washington, D.C.

¹⁶ *Shaping The Future: New Expectations for Undergraduate Education in Science, Mathematics, Engineering, and Technology*. National Science Foundation, 1996. NSF 96-139, http://www.nsf.gov/publications/pub_summ.jsp?ods_key=nsf96139.

¹⁷ *Teaching Reconsidered: A Handbook*. National Research Council, National Academy Press, Washington, DC: 1997.

¹⁸ *The Liberal Art of Science: Agenda for Action*. Washington, DC: American Association for the Advancement of Science, 1990b

settings. This approach maximizes effectiveness of the learning event. The Federal portfolio discussed above should be assembled and managed on this three part synergistic basis to be effective and to be properly leveraged.

In spite of the potential for leadership in science education reform, ocean scientists and educators found that joining the reform movement presented some formidable challenges. There was no common ocean education focus for scientists and educators. Aquariums, museums, science centers, the media, and marine laboratories were then, as now, valued vehicles for public informal education, but the research community lacked mechanisms for effectively engaging such institutions. The research community had no source for guidance in the unfamiliar task of sharing the fruits of ocean sciences research with a broader audience.

Well-planned programs of the National Oceanic and Atmospheric Administration (NOAA) in the 1980s and 1990s to coordinate educational programs on ocean and aquatic sciences brought change within NOAA's learning environments, but did not have a wide impact outside the agency. In 1997 the National Ocean Partnership Program (NOPP) began with a mandate for interagency ocean education programs and launched several key programs, however, the critical mass necessary to raise ocean education in the consciousness of ocean scientists – and beyond to the mainstream education community—had not yet been achieved. It had become clear that a new structure, national in scope and capable of integrating the efforts of multiple agencies and academic institutions with an ocean sciences mission, was going to be required in order to propel ocean sciences education into the forefront of the education reform movement and allow it to achieve its full potential as a cornerstone for improving national science education.

As a result of the momentum created by these developments, the question was asked within the National Science Foundation (NSF): Has the time come to catalyze a paradigm shift in the relationship between the ocean sciences research community and educators, students, and the general public? In late 1999, NSF sponsored a preliminary meeting to begin to address this question. In May 2000, a high-profile three-day workshop sponsored by NSF produced recommendations for strategies by which NSF and other Federal agencies could develop a nationally coordinated effort to improve and promote ocean sciences education for the benefit of society.

As a consequence, in 2002, NSF invested in the development of the National Centers for Ocean Sciences Education Excellence (COSEE) Network. This timely investment preceded the convening of the U. S. Commission on Ocean Policy (USCOP), the 2004 report of which stated that a nationally coordinated network for ocean sciences education was necessary. The primary goal of the COSEE Network was to integrate ocean sciences research and education through the “triadic” approach described above. In 2011, a decadal review of the COSEE program provided substantial evidence that this approach has been catalytic and successful in engaging scientists and educators to transform ocean sciences education for all by:

- Bringing current scientific research into education;

- Actively engaging scientists in the education process;
- Bringing the nature of science to educators;
- Presenting the ocean in an Earth system perspective; and
- Engaging informal and formal education partners and public audiences in the ocean science.

In an ocean education and outreach context, COSEE has demonstrated large success in bringing the three critical elements of education, ocean sciences research, and learning sciences together and doing so in a local setting where investments are most effective and have the greatest leverage. In some measure, the success of COSEE stems from multiple agency participation to have greater reach into the community of ocean expertise together with NSF’s access to the learning science community.

An obvious conundrum that arises from this transformational reform and the proposed FY14 OSTP strategy for managing the STEM portfolio, is the proposal’s tendency to narrow access to and integration of these three critical elements by somewhat isolating these individual “triadic” activities into particular agencies or institutions or even Directorates within an agency (e.g., NSF) without building infrastructure and a mechanism for strong collaboration between all three education, learning sciences and ocean sciences communities. In short, the required synergy – as well as the cornerstone role of the ocean sciences – is impeded by the increased fragmentation fostered in the proposed consolidation.

4. NOC Goals, Audiences and Metrics for Education and Outreach

a. Goals – At a national level, the overarching goal for education and outreach is to achieve a more knowledgeable citizenry with a globally competitive economy and a workforce prepared for the future. In the present context, we will refer to this as improving STEM “literacy” in general. The two NRC “Gathering Storm” reports addressed these challenges within a largely STEM degree framework. For the NOC, the shared, overall interagency goal follows from the national goal, but has a focus on the subset of ocean-related topics (i.e., ocean literacy and ocean education).

At the level of an individual agency or, at most, a small group of well-connected agencies, the education and outreach goals can take on additional dimensions beyond STEM or ocean education and ocean literacy, which may not be completely congruent across a broader array of agencies. Examples would be public education and outreach regarding the agency’s mission (“branding”), workforce development (“recruiting”), and even a form of “marketing” to obtain general public or legislative support for certain items of the agency’s activities. Such activities are often part of an agency’s mission or authorized in Congressional language.

The FY14 OSTP budget proposal for STEM consolidation includes 14 agencies or institutions¹⁹. Among these 14 bodies only two Federal Agencies appear to have education, per se, as part of the agency’s formal mission – the Department of Education (DoEd) and

¹⁹ USDA, DoC, DoD, DoEd, DoE, HHS, DHS, DoL, DoT, EPA, NASA, NSF, NRC, Smithsonian

the NSF, while the balance of agencies have been authorized to participate in education related to their primary missions (e.g., NOAA via the AMERICA COMPETES ACT). This “constellation” of authorities and programs is congruent with the “triadic” education reform described earlier in the way it brings the “Science Content Experts” into the overall Federal effort or portfolio. As proposed for FY14, the DoEd would have purview over all federally funded K-12 STEM initiatives, the Smithsonian Institution would receive the bulk of Federal funding for informal science education programs, and the NSF would receive the majority of Federal funds for higher STEM education. The DoEd, the Smithsonian, and the Nuclear Regulatory Commission are not members of the NOC and cannot therefore directly benefit from the opportunities provided by the NOC agencies for accessing the expertise or ocean-based education and outreach activities of those agencies. As discussed later, this creates impediments to interagency collaboration and to optimal leveraging of Federal investments.

In view of the breadth of specific education and outreach goals by level and by agency, it is not surprising that a national, top down strategy might be somewhat opaque when viewing it from a simple compendium of programs. In fact, the Federal agency portfolio of all education and outreach efforts can be likened to an ecosystem wherein each component performs best when supporting the overall goals as well as the local aims. Yet another analogy is a tapestry that is woven as a whole while individual contributions strengthen the entire cloth but differ in important local details. We were offered the latter analogy by a Federal manager in the context of best practices for interagency collaboration. This is discussed further in Section 7 and arises below in a discussion of measures for success.

b. Target Audiences – Depending on the goal chosen, ocean science education and outreach activities may focus on different target audiences or combinations of audiences from six general categories:

- | | |
|---|--|
| 1. Preschool | → ocean literacy |
| 2. K-12 students and/or teachers and/or parents | → ocean literacy, U.S. workforce, branding |
| 3. Pre-Baccalaureate students and/or teachers | → ocean literacy, U.S. workforce, branding |
| 4. Post-Graduate students and/or teachers | → U.S. workforce, branding |
| 5. Adult learners | → ocean literacy, marketing, branding |
| 6. Officials & Decision Makers | → ocean literacy, marketing |

The arrows indicate the primary education and/or outreach goal(s) mentioned earlier as we see them for each target audience. Of course, the nature of the target audience will alter the approach to a specific goal in significant ways. The ability of various agencies to share

with each other their “best practices” for reaching particular target audiences for specific goals is also a means to manage the portfolio for better leverage and to have a more effective “ecosystem” or a stronger “tapestry.”

One can view the Goals and Target Audiences for this complicated “ecosystem” or “tapestry” in two dimensions (tabular) as:

Goals		Target Audiences						
		PreSchool	K-12	UnderGrad	Teachers	GradSchool	Adults	Deciders
National	Competitive economy	Shared Goals & Target Audiences for NOC Interagency programs						
	Future US workforce							
	Knowledgeable citizens							
Agency	Branding	Shared Goals & Target Audiences for NOC Interagency programs						
	Marketing							
	Recruiting/Retaining							
Education	Formal (preK to 17+)	Shared Goals & Target Audiences for NOC Interagency programs						
	STEM literacy (informal)							
	Ocean literacy (informal)							

Here we indicate in green the areas likely to yield shared Goals and common Target Audiences for NOC interagency collaboration to be broadly effective. The FY14 OSTP STEM budget proposal can be described as an organization of the Federal Education portfolio with an emphasis on STEM. It is less clear to us whether the OSTP focus is on a) increasing the formal STEM degree pipeline, or b) increasing the STEM literacy of the general population, or some combination. This is important to clarify in terms of goals and target audiences, because different NOC agencies will participate more in one area of focus than the other, depending on their mission. Also in the proposed consolidation plan, the informal education role is assigned to the Smithsonian Institution, which is not a member of the NOC and does not usually work in collaboration with the Federal agencies, as a whole²⁰, where the ocean research and education expertise is greater and more accessible. Moreover, the need for growing the formal STEM degree workforce “pipeline” is not as clear to us as the need for improved STEM literacy in the general population. The interagency “tapestry” or “ecosystem” will operate better with more clarity in this regard and greater leverage could be expected. Note that most goals that are specific to an agency are not suitable for collaboration (shown in pink) and should be avoided as a basis for interagency collaboration.

c. Measures of Success – Generally the measures of success for education and outreach activities, particularly at the national level, are very long term and challenging to quantify. Examples might be:

1. Increase the number (or fraction) of citizens who are “literate” about scientific subjects and related societal issues (e.g., ocean subjects and issues).
2. Increase the number (or fraction) who can think critically and quantitatively.

²⁰ ORAP is aware of only the Interagency Working Group – Ocean Education (IWG-OE) where the Smithsonian participates in NOC activities.

3. Increase the number (or fraction) of U.S. citizens who choose STEM training and/or careers.
4. Ensure all U.S. demographic groups are similarly and proportionately represented in major STEM fields and/or careers.

Another tool to measure success is a “longitudinal study” that tracks individuals over many years to determine impacts on them from some earlier exposure or intervention. An example of this is the recent longitudinal study of National Ocean Sciences Bowl (NOSB) participants²¹. In both types of measurement the timeframe for assessment is typically one or more decades. This poses a challenge for assessing progress in a timeframe that allows feedback to the program and to decision makers who fund the programs and manage the overall portfolio. In the short run, taken as 3-5 years or so, the assessments are necessarily indicative and often qualitative. Indeed, the qualitative measures may be more important, particularly if an initiative is intended to increase the pipeline into STEM careers. Pre- and Post-event measures using questionnaires, tests of knowledge, and other assessment tools can evaluate the outcomes of the intervention. A few examples of qualitative measures for use in surveys of participants before and after an intervention for ocean subjects and issues are:

1. Gains in knowledge of scientific principles and enhancement of technical or problem solving skills.
2. Enhanced positive attitudes, even excitement, toward STEM literacy and ocean-based careers.
3. Increased self-confidence in one’s ability to converse and perhaps excel in STEM fields and ocean-based careers.
4. Increased knowledge of the value of STEM skills in the workplace and increased awareness of STEM and ocean careers.
5. Removal of any barriers to possible advancement in STEM and ocean literacy or education that may have existed prior to the intervention.

Questions that address self-efficacy, such as, “Are you are more informed about scientific subjects and related societal issues?”; “Are you more able to think critically and quantitatively about societal and environmental topics?”; “Are you more likely to choose a STEM education or an ocean-based career?” can provide evidence of impact.

The point here is not the specific examples given as illustrations but is to strongly suggest that similar questions should be asked in a standard way across the Federal portfolio of programs. Moreover, the standard measures should be sustained for a number of years to develop trends for assessments of these programs. In this way, the interagency “tapestry” can insure resiliency and maximal leverage for all its components. We see less value in short-term quantitative measures that simply count the number of participants reached or the

²¹ *Assessing the Impact of the National Ocean Sciences Bowl, A Systems Approach*. <http://www.nosb.org/wp-content/uploads/2010/07/Assessing-the-Impact-of-the-National-Ocean-Sciences-Bowl-A-Systems-Approach-2004.pdf>

hours of contact. These simple metrics can indicate the scope of a program, but not the actual impact or achievement toward meaningful goals.

d. Messaging – We use this term to represent the practice of communicating a value to change behavior versus educating to understand an issue or outreach to promote education itself. In some sense, messaging is the communication or translation of a particular conclusion rather than the ability to understand it. Communicating values to the public have changed behavior on a national scale and messaging can be an effective means to achieve a worthy purpose. Two environmentally related examples are the very successful campaigns against roadside litter in the 1960-70s and, more recently, recycling of household refuse. However, it is less clear that messaging can be used to directly advance an education or outreach goal such as STEM or ocean science literacy. An argument can be made that a message can be used to attract an audience to a venue where an education or outreach goal can be addressed, but this must be done carefully when using Federal funds to avoid the appearance of advocacy or agency/institutional marketing.

5. Ocean Workforce Development

a. The Outlook – We quote from the NOP Implementation Plan as an example:

“Ocean industries are a major employer. In 2010, U.S. commercial ports supported more than 13 million jobs. Similarly, in 2011, commercial fisheries supported 1.2 million jobs and \$5.3 billion in commercial fish landings, and marine recreational fisheries supported 455,000 jobs. As of March 2012, energy and minerals production from offshore areas accounted for about \$121 billion in economic contributions to the U.S. economy and supported about 734,500 American jobs. Offshore wind energy has the potential to directly support 20.7 jobs for every megawatt-hour generated. Installing 54 gigawatts of offshore wind capacity in U.S. waters would create more than 43,000 permanent operations and maintenance jobs.”

Not all members of this workforce require STEM degrees in ocean related fields, and there are numerous other sectors – both public and private – that do require such expertise in significant numbers. It has been estimated that 1 in 6 U.S. jobs are related to ocean-based activities and those activities account for over 16% of the U.S. Gross Domestic Product²². Moreover, the future is likely to increase these numbers, as more economic activities move offshore or use the oceans (e.g., renewable energy development, aquaculture, transportation, geo-engineering, etc.) and the need for conducting these activities in a safe, effective, and environmentally sound manner grows more challenging.

b. Non-Federal Ocean Workforce Development – The economic growth of the U.S. is dependent on a STEM literate – ocean literate workforce. The landmark NRC report “Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future” presented a sobering prospectus of the U.S. Among the indicators of the state of the U.S. economy were: 1) low-wage employers created 44% of U.S. jobs, while

²² *State of the Coast: The Ocean Economy.* <http://oceanservice.noaa.gov/facts/oceaneconomy.html>

high-wage employers created only 29%, 2) a company can hire eight young professional engineers in India for the cost of one in the U.S., and 3) foreign country undergraduate students (France, 47%; China, 50%; Singapore, 67%) receive significantly higher number of degrees in natural sciences or engineering than the U.S. (15%)²³. The report was reprinted by the same committee about five years later in 2010²⁴ finding:

“The unanimous view of the committee members participating in the preparation of this report is that our nation’s outlook has worsened. Despite the many positive responses to the initial report, including congressional hearings and legislative proposals, America’s competitive position in the world now faces even greater challenges, exacerbated by the economic turmoil of the last few years and by the rapid and persistent worldwide advance of education, knowledge, innovation, investment, and industrial infrastructure. Indeed the governments of many other countries in Europe and Asia have themselves acknowledged and aggressively pursued many of the key recommendations of Rising Above the Gathering Storm, often more vigorously than has the U.S.”

The consequences of this decline in engagement and achievement in STEM and in STEM literacy in the general population are manifold, however two of the most significant are:

1. Threats to the workforce of tomorrow necessary to generate innovation and economic growth and international competitiveness and
2. Failure to develop a scientifically literate citizenry capable of making informed decisions about complex, societally critical issues.

The non-Federal ocean workforce must be cultivated to ensure U.S. economic security. Examples of strategies to achieve this include:

1. Professional development for K-12 educators that expose them to ocean scientists, ocean science content, and advancements in learning sciences, including the opportunity for authentic ocean science research experiences.
2. Integration of exemplary ocean science education materials into K-12 curricula and visitor programs at informal science education institutions.
3. Internship opportunities for high school and undergraduate students at U.S. marine laboratories.
4. Professional development for ocean scientists to help them better communicate the results of their research.
5. Leveraging the U.S. major ocean science research facilities to integrate ocean science education and outreach activities (such as delivering live feeds from the U.S. research fleet into classrooms, aquariums, science centers, Boys and Girls Clubs, etc.).

²³ *Rising Above the Gathering Storm: Energizing and Employing America for a Brighter Economic Future*. Washington, DC: National Academies Press, 2007.

²⁴ *Rising Above the Gathering Storm, Revisited*. Washington, DC: National Academies Press, 2010.

An ocean-literate workforce is required to fill positions in commerce, transportation, energy, food production, food safety, national security, and recreation/tourism. This workforce will support the country in addressing a wide range of challenges, including increased risks to coastal communities due to extreme events and the effects of climate change; safe and efficient maritime transport; and sustainable recovery of ocean-based energy resources, just to highlight several. No matter how the U.S. economy evolves in the next few years, our nation's citizens must be ocean literate and ready to face the challenges ahead in the coming decades.

c. Federal Ocean Workforce Development – We include this topic here because we believe the importance to our nation, and the Federal Government in particular, of having a high-quality, highly relevant, flexible, expandable STEM-degreed and ocean literate workforce cannot be overstated. It is, of course, a critical element for all the NOC agencies. Furthermore, a means to facilitate this end can also contribute to the framework for formal and informal education discussed above. Example opportunities include:

1. Enhance websites and recruitment tools to aid applicants in applying for federal jobs that are perceived as exciting places to work on important problems.
2. Increase attention to recruiting from the under-represented and under-served communities.
3. Provide greater opportunities for exposure to the ocean science enterprise.
4. Engage the private sector and governmental agencies at all levels to create personnel exchanges (e.g., IPA) between government and the private sector.
5. Engage the private sector and governmental agencies at all levels to work collaboratively with colleges and universities to foster “continuous learning” within the existing Federal workforce.
6. Explore methods to exchange employees for temporary assignments across the Federal workforce.

We summarize this section by slightly adapting two recent findings from the NRC study on DOD STEM workforce needs, in the belief that these are equally relevant to the Federal workforce as a whole:

Finding 2: *“The STEM issue for [NOC agencies] DOD is the quality of its workforce, not the quantity available. The [NOC agencies] DOD needs a suitable share of the most talented STEM professionals. The decisions they make within [NOC agencies] DOD are highly leveraged, impacting the efforts of very large numbers of people and enterprises both inside and outside the government.”*

Finding 5: *“For [NOC agencies] DOD to recruit top STEM talent in competition with commercial firms, universities, and others, [they] it must commit to improving the STEM workforce environment. The [NOC agencies] DOD must become, and be perceived as, an attractive career destination for the most capable scientists, engineers, and technicians who are in great demand in the global talent marketplace.”*

6. Ocean Literacy in the General Population

All citizens should have the opportunity to become ocean science literate. To achieve an ocean literate society, ocean sciences must be valued and integrated into educational practice, research, standards, curricula, textbooks, and assessments. In addition, both formal and informal science educators must draw upon the learning sciences and ocean scientists. With the release of the NGSS and the understanding gained by the learning sciences community over the last decade of how to best achieve STEM learning, the 14 Co-STEM Federal agencies have a special opportunity to support national ocean literacy.

a. K-12 Formal Education – The emergence of the Next Generation Science Standards (NGSS) offers a new and powerful means to increase the use of coherent ocean science examples in K-12 STEM education (see Appendix A for a short overview of the NGSS adapted from material provided to ORAP by Dr. Philip Bell, University of Washington and NRC). The implementation of the NGSS can be assisted by focusing on published and tested Ocean Literacy Principles and Fundamental Concepts²⁵. Professional development for educators to these ends are encouraged and should introduce teachers to the online availability of real-time and predictive information from IOOS/OOI/Inner Space Center and other ocean data driven programs for use in experiential elements of the NGSS. The workshops should also increase the availability and distribution of ocean science content material for the teachers to use that is keyed to the NGSS outcomes. The teachers will also need support²⁶, including professional development and possibly technology training. Engagement by ocean scientists is critical, as noted in several recent studies, because the scientists not only can share current knowledge of the discipline, but can also effectively assist teachers in overcoming their hesitation to conduct learning activities that promote student understanding of the nature of science²⁷ when both are partnered with learning scientists, as described earlier.

Workshops that focus on ocean literacy principles and involve ocean scientists together with other providers of ocean knowledge (television, filmmaking, magazines, museums, industry, aquaria, etc.) should be encouraged to create linkages and to tailor the connections between formal and informal learning contexts that will build coherence during the K-12 continuum. This could include a certification process for informal science education in the ocean sciences. In addition, this will develop conduits between ocean science research and discoveries and informal science content providers, who may lack access to current, accurate, and leading ocean science. This coherence can only be achieved through continuity and broad availability of programs at the local level. We note that the national goal of greater science literacy is also very well-served by greater ocean literacy given the natural interests in ocean issues among the general population.

b. Informal Education and Outreach – Unless an individual seeks formal training in the ocean sciences or related subjects, opportunities to learn about the ocean are usually discreet

²⁵ *Ocean Literacy*. <http://oceanliteracy.wp2.coexploration.org/>

²⁶ *Professional Development for Science Teachers*. <http://www.sciencemag.org/content/340/6130/310.abstract?sid=84d0d747-8ad4-466a-8901-d361c65403c1>

²⁷ *Informing an Effective Response to Climate Change*. Washington, D.C.: National Academies Press. 326 pp. http://www.nap.edu/catalog.php?record_id=12784

and scattered. These opportunities are often also characterized as Free-Choice Learning²⁸ which captures the voluntary, episodic and varied means by which most individuals will gain knowledge about our oceans. These opportunities to learn may occur in the K-16 classroom, but are more likely to accrue outside of formal schooling where learning is not the primary activity, and thus, the discreet and scattered events may lack an overall framework of understanding to enable a coherent view to be reached by the learner about the oceans and their processes. Fostering a framework to assist these individuals in building a more comprehensive and coherent understanding of the oceans provides a great opportunity to leverage agency education and outreach activities in order to raise ocean literacy across the general population. Lifelong learning is a hallmark of a STEM career, however, it should be fostered in the general population as well. Here again, there is an opportunity to create coherence between learning events of children and their parents or other adults so that we reach both today's citizens and those of tomorrow (e.g., EPA regional investments, NMEA, COSEE resources). The framework for creating this coherency over a lifetime is also a priority for the NGSS in the view of ORAP.

The engagement of other providers of ocean knowledge (television, filmmaking, magazines, museums, industry, aquaria, etc.) in the workshops described above will give them insights on how to link their activities with the formal education activities of their audiences while providing professional development opportunities that provide them with current ocean science content. These professional development opportunities should also involve the other two key elements of the “triadic” educational reform; learning scientists and ocean scientists. Here is where the NOC agencies have a role that cannot be provided by others. Moreover, by connecting to the students in a coherent manner, the parents of the children will be entrained in a more coherent view of STEM methods and ocean literacy. It is win-win across several generations of a broader population. The Federal portfolio and NOC activities can be focused to these ends and serve the nation well.

7. Best Practices for Interagency Cooperation

a. When does interagency cooperation add value? – As discussed earlier, mission driven agencies will have specific educational and outreach goals (e.g., workforce recruiting or “marketing” or “branding”) that are necessary for that agency and not likely to yield useful collaborative activities, but many goals or approaches are, in fact, shared at some degree, particularly in regard to shared overall national goals such as greater STEM literacy. Collaboration on such common goals can quickly add value if the rewards outweigh the barriers to collaboration among agencies. Productive Federal agency collaboration on common goals with common measures of success will foster a culture of cooperation and provide the means to create broader partnerships beyond the Federal system (e.g., Academia, State & local government, NGOs, societies, oceanaria, science museums, industry, etc.). These all contribute to greater leveraging of federal resources. It is important for OMB to understand that collaboration between units within agencies and between agencies does not necessarily indicate redundancy. To fully leverage federal investments, interagency cooperation and collaboration is essential.

²⁸ Rowe, Shawn. *Free Choice Learning Concepts*. University of Oregon, <http://blogs.oregonstate.edu/freechoicelab/>. See Appendix B for more information.

Common measures for success and clear identification of target audiences will improve the assessment of progress on shared goals and encourage the use of approaches that embrace best practices as mentioned earlier. Fear of duplication is often exaggerated in the absence of clearly distinct goals, differing target audiences, and common measures for success. Programs may appear duplicative when their specific STEM content is quite different. For example, internships used by agencies for recruitment to specific departments or regions will have a different content than an internship designed to increase diversity in a discipline.

Indeed, some “overlay” or “overlap” in programs is probably the best way to manage a diverse portfolio to ensure continuous innovation for best practices. Such overlap also avoids the “gapping” that can come from too much fragmentation or stove piping under a simple consolidation. Managing such a portfolio to have a robust “tapestry” or resilient “ecosystem” requires a common framework for assessment even if the details otherwise differ. This type of collaboration will increase impact(s) for the U.S. and therefore increase its efficiency and effectiveness of investments in the long term.

Examples of good guidelines and approaches for effective interagency collaboration can be grouped into cultural practices and into processes as follows:

Culture

1. Focus only on shared goals using common measures of success (avoid mixing in agency recruiting, “marketing” and “branding” activities).
2. Efficiency requires like-minded people who “buy-in” to the value of working collaboratively.
3. Trust is an important part of the collaboration, especially knowing that each partner will follow through with their commitments. It takes times to build these relationships.
4. A champion is needed from the outset – it could be an agency, organization, or an individual – but it should be a neutral, knowledgeable broker with no direct authority or individual agency agenda. For example, AGU and NMEA served as neutral brokers in the development of the Ocean Literacy Principles.

Processes

Clearly identify the specific goals and target audiences.

1. Less process is better than more process, and more informality rather than formality often leads to ease of participation with more exchange of ideas and best practices.
2. Avoid new (i.e., more) working groups – use existing forums.
3. Ensure working group members are empowered within their own agencies to agree and to implement (e.g., can speak for all relevant agency programs).

4. Create and maintain a shared inventory of agency and collaborative programs, which is both simple to build and to maintain.
5. Once a framework is established, regular meetings are necessary to bring together those who are being funded to maximize collaboration and avoid unwanted duplication. This will increase return-on-investment by each and by all.
6. Create resources for specific audience levels. A matrix/database of these resources that are available across the agencies is a very useful tool.

We gathered the above from informal interviews with current and past Federal program managers. One comment about a successful example is worth repeating:

One of the challenges working under the interagency USGCRP (with USGCRP calling the shots) is that the agencies tended to do their own thing as directed by their missions. The role and benefit of “top down” USGCRP involvement was to set the agenda, develop tools, facilitate dissemination of all activities, both common and individual agency. Then all are able to create the “tapestry” – not a slice of the pie – and to set up some significant cross cutting activities, which is where the added value is.

We emphasize that clearly shared goals, known target audiences and common measures for success will foster this at all levels as described earlier. Another interesting comment which reflects this point was:

Different agencies have different assets – some have more knowledge to contribute than they have money. It is most effective to manage collaboration as a whole with everyone contributing in the way that they can. This can be difficult, as agencies that contribute more money, generally want more control. You do need to keep the branding and marketing of each agency, but no one agency is big enough to solve the problems with STEM education, so everyone wins if they are part of a whole.

b. Impediments to interagency cooperation – There are many forms of impediments from procedural to legislative. Some of these are warranted. Others may not be recognized by upper management who is primarily charged with optimizing to overall agency mission objectives, with “marketing” the mission, and with “branding” the agency while minimizing any perception of agency risks to its programmatic integrity. As seen earlier, “marketing” and “branding” are not areas where the best collaboration across agencies is to be found. At budget time, undue inquiry in regard to perceived overlaps and redundancy in interagency programs can adversely affect upper management and cause under-reporting, re-labeling and less collaboration at the working level as a consequence.

Meanwhile, at the program manager level, the practical decision is a balance between the gains for his or her program versus the additional effort and the degree of support from above. Often, there is measurable benefit to collaboration that does not have much visibility or priority higher in the system. Among the procedural impediments there can be

- Difficulties in moving or combining funds across or between agencies.
- OMB review structure encourages “stove piping” rather than collaboration between agencies.
- Department of Education is not a part of the NOC or the interagency working groups.
- Lack of funding flexibility to pursue shared goals for greater overall leverage.

Additionally, the focus on apparent duplication and overlap in STEM education programs can have the unintentional consequence of fragmenting delivery, dis-incentivizing collaboration even on shared goals, and thus preventing comprehensive and coherent programming. If we limit one agency to deliver one type of program or programming in a specific area, then education providers (the Teachers) are left with attempting to piece together effective programs from an array of sources with different goals and requirements. In addition, ocean science content in particular may be lost in the shuffle of consolidation, as it is not traditionally viewed as a “core science”. A focus on preventing duplication also prevents creation of comprehensive programs that bring students from one level to another or provide exposure to an array of choices in STEM. The FY14 OSTP STEM budget proposal may be a step in the right direction and, done well, could overcome many of these impediments. Our recommendations for assisting this endeavor to be done well can be found in Section 6 following.

c. Examples of Success where interagency cooperation added value:

1. Developing and using a Common Framework across agencies (e.g., the development of the Ocean Literacy Principles and Fundamental Concepts)²⁹.
2. Linking ocean science researchers to educators and learning scientists (i.e., National COSEE Network and Climate Change Education Partnership models).
3. Using the National Oceanographic Partnership Program³⁰ and the Interagency Working Group on Ocean Education (IWG-OE) to work together on a single project (NOSB, Ocean Literacy Initiative, EcoHab, etc.)³¹.
4. Developing and supporting programs that broadly educate scientists on how to effectively communicate to the general public (COSEE’s professional development programs for ocean scientists³², CESU – Cooperative Ecosystems Studies Units³³).

²⁹ Hodder, Jan. *Leveraging Ocean Science Education Opportunities*. <http://www.nopp.org/wp-content/uploads/2012/08/ORAP-Presentations1.pdf>

³⁰ *National Oceanographic Partnership Program*. www.nopp.org

³¹ *National Ocean Sciences Bowl*. <http://www.nosb.org/>.

³² *Communicating Ocean Science for Informal Audiences (COSIA)*. Rutgers Institute of Marine and Coastal Sciences. <http://marine.rutgers.edu/main/IMCS-Outreach/Communicating-Ocean-Science-for-Informal-Audiences-COSIA.html>

³³ *Cooperative Ecosystem Studies Units (CESU) Network*. <http://www.cesu.psu.edu/>

5. Using innovative approaches to ocean education (e.g., GoMA³⁴, West Coast Governor's Alliance³⁵).

A major success in this arena over the past decade has been the National COSEE Network and the bridges created to other networks. The impacts of this NSF funded initiative include the formation of a highly functioning national ocean education network that influenced the development of the Ocean Literacy Principles and the NGSS ocean science learning goals, while broadly providing professional development both to formal and informal science educators and ocean scientists. Although primarily funded by NSF, from its early days in the NOPP framework, both NSF and NOAA program managers and Smithsonian Institution staff have served as ex-officio members of the Network's governing council along with others. This provided the opportunity for the program managers to identify and discuss needs of the ocean science education community and for the Smithsonian to leverage investments in their ocean science education activities. The partnership of COSEE with NSF, NOAA, and the Smithsonian moved the ocean literacy movement forward and NOAA grants to COSEE Centers allowed the Centers to expand their effort and national reach. Evaluation of COSEE's initiatives demonstrates that the National COSEE Network has provided ocean scientists with opportunities and tools to educate the public and assist in the preparation of our country's future workforce. Over the last decade, the National COSEE Network has engaged over 2000 ocean scientists in a host of education and professional development programs. Over 20,000 thousand educators have participated in COSEE programs through 14 regional Centers and the National COSEE Office activities. The Network, comprised of over 275 institutional partners, has brought ocean science to tens of thousands of students through educators that have been trained by teams of education professionals and ocean scientists. Much of this has been well documented in the report produced for COSEE's decadal review³⁶. COSEE's "excellence" is due in part due to its diverse partnerships across agencies as well as many levels and sectors. In the end, all education and learning is local (to borrow a phrase).

Well-established partnerships with formal and informal education institutions will ensure that future advances and discoveries in ocean sciences research are efficiently integrated into K-16 education programs and instructional materials, as well as into public programming across the country. The next generation network for ocean sciences education should be poised to incorporate the products and results of broader Federal investments such as those emerging in cyber infrastructure to provide new capabilities and tools with which scientists, educators, students, and the public can be brought together. Research on science learning and teaching and new research-based understandings of how to better serve diverse audiences will allow the next generation to further integrate ocean sciences research and education.

³⁴ *Ensuring Environmental Literacy*. Gulf of Mexico Alliance. http://www.gulfofmexicoalliance.org/issues/environmental_edu.php

³⁵ *Ocean Awareness and Literacy Action Coordination Team*. West Coast Governors Alliance. <http://www.westcoastoceans.org/index.cfm?content.display&pageID=83>

³⁶ *A Decade of Excellence*. Centers for Ocean Sciences Education Excellence. <http://www.coseeolc.net/>

Other examples of successful networks include the regional New England Ocean Science Education Collaborative (NEOSEC), Coastal Ecosystem Learning Centers (a federation of 25 aquariums coordinated by the Coastal America Partnership), Sea Grant institutions, and the National Estuarine Research Reserves. Many of these have been able to maintain or grow funding by engaging the private sector and other regional resources in addition to federal funding. These examples of collaborative success share certain key attributes starting with the understanding that:

1. In order to address needs, a network is essential to providing coordination, leveraging resources, and sharing of best practices.
2. There is value in other kinds of collaborative efforts that may reach different audiences, where a national network may operate through regional nodes.
3. Significant impacts are achievable within a national framework embracing regional efforts which can build a sense of community where it previously did not exist.
4. There is a need for impact evaluation, which must be sufficiently resourced.
5. Bridges to and engagement with the private (industry, etc.) sector enhances the ocean education enterprise.

8. Leveraging Investments to Maximize Educational Impacts

In the present context we take leveraging to mean:

“use of well-aimed NOC Agency and Federal resources to gain relatively strong influence and greater returns”

This meaning implies several features starting with a smaller Federal investment than a national one counting all resources (e.g., private, state, local, etc.). In that case, the other providers of resources should be motivated to join in the collaboration for much the same reasons of increased leverage in the combined outcomes for themselves. This implication also scales down to the individual agencies of the NOC who ought to be motivated to participate amongst NOC agencies in order to leverage their investments as well as the local providers of both formal and informal education. While this may seem obvious, the establishment of mutual leverage will be the key to success. It is not clear to us that the DoEd or Smithsonian are positioned to be close collaborators with the essential resources in the NOC agencies. There is currently no infrastructure to support the necessary connections, nor is there a proposed plan for facilitating them.

a. The key to leveraging efforts is to provide a common vision or conceptual framework, guidelines for interactions, and infrastructures for shared resources. The OSTP FY2014 proposed budget is a start in that direction but the aim and approach must be made clearer and the means to foster greater “triadic” collaboration across agencies and institutions both public and private needs to be developed. The new NGSS offers an educational approach and framework to this portfolio while also offering a means to obtain maximum leverage.

b. As discussed earlier, the specific program goals, target audiences, and measures of success must also be taken from a shared taxonomy. We are not saying that all programs must have the same specific goals, audiences or measures, but they should be identified from a shared list that clearly follows from a shared vision and approach.

c. A culture of collaboration – based on regularly updated and published best practices as described earlier – must be created and rewarded. Efficient processes rather than cumbersome forums should be the norm. To these ends, leadership can minimize impediments that often lurk in the system as described earlier.

d. With the above in place, a national network that connects and supports the three transformative elements – Teachers – Facilitators – Scientists – must be supported so that each individual collaborator can readily add to the shared resources, while being able to draw more in-kind than provided. With such a network in place all will feel that their investments are well-leveraged to the larger, national goal.

9. Effectively Linking Informal Ocean Education Activities to Education Standards

The Next Generation Science Standards (NGSS) offer a unique and extraordinary opportunity to link formal and informal activities via programs and a Federal portfolio designed to do so. Since the NGSS are based on a more experiential approach to learning in order to grow individual reasoning and quantitative skills, opportunities to provide ocean-based materials to formal education curricula are clear, but equally important is an effort to shape “free choice” learning opportunities so they reinforce the formal curriculum experiences. To this end, NOC agencies can work together to increase an emphasis on ocean systems within the earth sciences component of the NGSS for the student experiences. This is perhaps the most effective way to introduce the generic STEM knowledge and skills because the natural sciences of the earth and oceans are of intrinsic interest to many learners. By coupling formal and informal experiences, the overall effort to improve STEM literacy can reach the entire population better than with any other STEM topic.

10. Key Recommendations

ENDORSE AND LEVERAGE NGSS: The NOC should formally endorse the NGSS as the framework with which to align the NOC agencies’ education and outreach goals, both for formal and informal science education (see Section 6 herein). In particular, the NOC agencies should offer ocean science experience and expertise as the cornerstone of the earth science component of the NGSS. To this end, NOC should invite the Department of Education, Council of State Science Supervisors, and the National Science Teachers Association to work with the NOC in the context of the NGSS to this end. Lastly, the NOC should foster recognition that ocean science subject matter is a natural and socially-relevant means to improve overall U.S. STEM education via the NGSS.

FORM A ROBUST BASIS FOR THE FEDERAL STEM PORTFOLIO: The basis or framework for assembling, managing, and leveraging a Federal STEM portfolio should be

improved and made clearer to meet national needs and goals. The ORAP generally agrees with the notion of such a portfolio and offers a framework in this report to obtain the greatest impact and leverage. First, however, the balance between two aims must be established:

1. Increasing the formal STEM degree pipeline, and
2. Increasing the STEM literacy of the general population.

ORAP believes that STEM skills for jobs not requiring a four-year college degree and STEM literacy in the larger population are as important national concerns as the formal STEM pipeline itself. The Federal STEM portfolio should be assembled and managed on the transformative “triadic” approach described in Section 3, which must be fully synergistic to be effective and properly leveraged. Here is where the NOC agencies have a role that cannot be provided by others. Most NOC agencies reach from the Federal level to local institutions (e.g., labs, funded researchers, etc.) where the science content is developed and the education is delivered. Moreover, by connecting to the students and learners in a coherent manner, the parents of the children will be entrained in a more coherent view of STEM methods and ocean literacy. It is win-win across several generations of a broader population. The required synergies, as well as the cornerstone role of the ocean sciences, are likely to be impeded by the increased fragmentation fostered by a simple consolidation.

CREATE A NETWORK (of NETWORKS): The NOC should advocate for and support a national network that bridges many existing and dispersed networks and societies. The overall network (of networks) should achieve implementation of a mutual support system via access to databases of resource materials and professional development opportunities among Teachers – Learning Scientists – Ocean Scientists as basis for transformation of ocean education and STEM literacy. These networks must have shared, measurable performance metrics (as described in Section 4 herein) focused on achieving a more ocean-literate public and a strong U.S. workforce, as indicators for program and national success. We see less value in short-term quantitative measures that simply count the number of participants reached or the hours of contact. Appropriate performance measures should recognize that significant achievement will occur over decades rather than in months to years. Access to state of the art technologies should be integrated as the mechanism for conveying ocean interest.

UNDERSTAND AND OVERCOME THE IMPEDIMENTS TO BETTER PARTICIPATION IN THE OCEAN ENTERPRISE BY UNDER-REPRESENTED GROUPS, PARTICULARLY MINORITIES: Minority participation in STEM fields is generally low, but improving in recent decades. It is notable that little, if any, improvement can be seen in degrees and professions related to ocean science and the ocean industry. The reasons for this disparate outcome for ocean activities are not clear to ORAP, except that approaches employed for improving representation of women have not worked as well for minorities (or were not the reason for improved female participation). We see indications that the differences are possibly a matter simply of awareness of opportunities or as deep as generational and cultural influences. In any case, a better approach must be found, and we suggest a good place to start is with a focused study of “lessons-learned” from both

successful and less-so institutions and programs (e.g., EPP/NOAA) and to also engage social scientists in the “triadic” approach advocated here. A remedy for this situation is a high national priority to insure a growing enterprise of balanced participation for an increasingly diverse population. We note that the mission agencies may be best situated to lead in this endeavor and have a need to balance their own workforces.

IMPROVE COLLABORATION ACROSS THE NOC AGENCIES AND WITH OTHERS: Interagency collaboration on common goals with clearly identified target audiences for each effort, and shared measures of success must be fostered and rewarded (see Section 4 herein). In addition, agencies should develop, collect and strongly foster “best practices” as we have indicated in Section 7 herein from our interviews with Federal managers. To avoid budget impediments to this collaboration, OMB should consider assigning examiners as overseers to the key interagency collaboration plans and portfolios. In the longer run, some thought could be given to rotations among OMB examiners between agencies to expose them to a number of agencies over time.

EXPLOIT “FREE CHOICE” INFORMAL LEARNING IN PARTNERSHIP WITH THE PRIVATE SECTOR, INCLUDING INDUSTRY: Using the NGSS framework and the above network of networks, engage television, filmmaking, magazines, museums, industry, aquariums, etc. in the development and representation of ocean science content with the support of ocean science experts. Make a strong statement for industry to be involved in this education and outreach effort. Many industries rely on a productive and healthy ocean (shellfish, tourism, etc.) and will employ increasing numbers of ocean STEM graduates, while simultaneously seeking support from the general public for their activities (offshore renewable energy, oil & gas production, aquaculture, transportation, etc.). The basis for a mutual partnership is clear. Bring in the major sectors at a very high level of governance (e.g., API) to the network recommended above and encourage industry participation on a regional and/or sector basis with connections broadly at the local level.

FOSTER PROFESSIONAL DEVELOPMENT: Recommend that Federal agencies support professional development programs for educators and ocean scientists in general and in their own ranks. The professional development is to enable both formal and informal ocean science educators (teachers, journalists, docents, etc.) to become better educators and scientists to become better communicators. A certification program for informal educators in the ocean sciences (that incorporates the NGSS and Ocean Literacy Essential Principles) should be developed in conjunction with the ocean science community. This is an activity that the recommended network could implement. Similarly, this initiative should offer guidance to ocean scientists on how to more effectively contribute to education and outreach. In the end, the nation obtains maximum return by linking and enabling the triad of Teachers – Learning Scientists – Ocean Scientists to work together.

Appendix A – Short Overview of Next Generation Science Standards (NGSS)

What is science learning?

Consensus – Six strands of scientific proficiency:

1. Developing Interest in Science
2. Understanding Science Knowledge
3. Engaging in Scientific Explanation and Argument
4. Understanding the Scientific Enterprise
5. Engaging in Scientific Practices
6. Identifying with the Scientific Enterprise

Educational standards are:

- Collective conversations about which cultural achievements should be a shared good for all;
- Strong strategy for possibly transforming whole education system; and
- Principally about promoting equity by equalizing access to opportunities to Learn.

Major Educational Goals of the Framework:

- Coherent investigation of core ideas across multiple years of school; and
- Learners should explore a core idea by engaging in the practices and making connections to crosscutting concepts.

Understanding Develops Over Time

- Expert knowledge is structured around conceptual frameworks;
 - Guide how they solve problems, make observations, and organize and structure new information;
- Learning unfolds over time;
- Learning difficult ideas takes time and often come together as students work on a task that forces them to synthesize ideas;
- Learning is facilitated when new and existing knowledge is structured around the core ideas; and
- Developing understanding is dependent on instruction.

NGSS Dimension 1: Science and Engineering Practices

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

NGSS Dimension 2: Crosscutting Concepts

1. Patterns
2. Cause and effect
3. Scale, proportion and quantity
4. Systems and system models
5. Energy and matter
6. Structure and function
7. Stability and change

NGSS Dimension 3: Core Ideas Across Four Disciplinary Areas

1. Physical Sciences:
 - Matter and its interactions; Motion and stability; Energy; Waves
2. Life Sciences:
 - Structures & processes; Ecosystems; Heredity; Biological evolution
3. Earth & Space Sciences:
 - Earth's place in the universe; Earth's systems; Earth and human activity (including climate change)
4. Engineering, Technology & Applications of Science:

- Engineering design; Links among engineering, technology, science and society

Promoting Coherence in a Complex System

1. **Horizontal Coherence:** curriculum, instruction, and assessment-related policies and practices are all aligned with the standards, target the same learning goals, and work together to support students' science learning.
2. **Vertical Coherence:** shared understanding at all levels of the system (classroom, school, school district, state, and national) of the goals for science education (and for the curriculum) that underlie the standards.
3. **Developmental Coherence:** in the sense that there is a shared understanding across grade levels of what ideas are important to teach and of how children's understanding of these ideas should develop across grade levels.

Appendix B – Summary of “Free Choice” (Informal) Learning Concepts

Free-Choice Learning (FCL) Involves:

- High internal motivation;
- Socially meaningful or personally meaningful activity;
- Activity that is just beyond one’s current level of competence;
- Connecting with prior knowledge and experience; and
- “Flow” experiences.

FCL as a framework also focuses on continuity and customization in learning with an:

- Emphasis on lifelong learning;
- Emphasis on learning in multiple contexts; and
- Emphasis on individual, family, and community trajectories of learning.

Opportunities to learn about the ocean and ocean sciences are discrete and scattered.

Oceans (and other ecosystems in general) are not a priority in K-12 teaching.

Most of what people know about the ocean they learned outside of school in situations with a great deal of choice and control where learning itself is not the number one priority.

Other sources (e.g., television, magazines, museums, aquarium visits) are often not connected by learners explicitly.

Learners and educators need tools and processes for creating connections (build coherence) across learning contexts and across the lifespan.

- Formal to formal;
- Formal to informal; and
- Informal to informal.

Linking informal contexts and programs to NGSS requires the following professional development:

- For K-16 teachers on ocean literacy principles so that they can work to create continuity across formal schooling. Otherwise students’ experiences with ocean science concepts are still discrete and scattered within schooling; and
- For informal educators (broadly) to understand NGSS and make linkages in their exhibits, writing, programming, filmmaking, etc.

Technology can expand opportunities.

There is a general assumption that living near the ocean makes it easier to know and care about it. There is almost no evidence to support this concept.

Access to the ocean provides experiences that can promote lifelong learning and caring about the ocean. There is plenty of evidence to support this concept.

New conversations about the role of engaged universities can help in bridging ocean science content gaps and methodologies based on the learning sciences.

Older one-way communication models of extension and outreach as important elements of university-based research are giving way to two-way models of engaging communities, students, and publics in the scientific enterprise. In ocean sciences, this process has little direction or shared goals.

Appendix C – Summary of Ocean Literacy Principles

In October 2005, several national organizations including National Geographic Society (NGS), National Oceanic and Atmospheric Administration (NOAA), Centers for Ocean Sciences Education Excellence (COSEE), College of Exploration, and the National Marine Educators' Association (NMEA) published *Ocean Literacy: The Essential Principles of Ocean Sciences K-12*, a guide containing seven essential principles and forty-four fundamental concepts that currently define ocean science literacy. This definition and the principles and concepts were the result of discussions among a hundred scientists and educators, and serve as a national standard for ocean science education. The principles and concepts have also inspired several other countries to develop similar guides in their own languages and have served as a model for other scientific disciplines in the United States. In 2013, a second version of this guide (Ocean Literacy Network, 2013) was published to address scientific and societal issues that have emerged since the original publication, such as ocean acidification, and recent developments in education, such as the Next Generation Science Standards. The Essential Principles and Fundamental Concepts are available online at <http://www.coexploration.org/oceanliteracy/documents/OceanLitChart.pdf>.

In addition, a 2010 guide, *The Ocean Literacy Scope and Sequence for Grades K-12* (NMEA, 2010) was developed with input from over 150 members of the ocean sciences education and research community. This publication provides educators with guidance on what students need to learn in different grades in order to achieve full understanding of the essential principles.

Ocean literacy as now defined is an understanding of the ocean's influence on people – and people's influence on the ocean. An ocean-literate person:

- understands the essential principles and fundamental concepts about the ocean;
- can communicate about the ocean in a meaningful way; and
- is able to make informed and responsible decisions regarding the ocean and its resources.

There are currently seven “essential” principles and each of the principles listed below is supported by multiple fundamental concepts:

1. The earth has one ocean with many features.
2. The ocean and life in the ocean shape the features of earth.
3. The ocean is a major influence on weather and climate.
4. The ocean made earth habitable.
5. The ocean supports a great diversity of life and ecosystems.
6. The ocean and humans are inextricably interconnected.
7. The ocean is largely unexplored.

The Essential Principles and Fundamental Concepts represent content that does not always fall within the core science disciplines, which are part of the usual K-12 curriculum. However, the principles clearly demonstrate the interdisciplinary nature of ocean sciences. Educators can use the Fundamental Concepts to fulfill and go beyond the recommendations of the new Next Generation Science Standards. They provide coordination, consistency, and coherence for ocean sciences education.

Appendix D – Report Contributors and Acknowledgements

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Acknowledgements

Numerous individuals and organizations contributed in many ways to the preparation of this report. ORAP would like to particularly thank Professor Phillip Bell/University of Washington; Professor Shawn Rowe/University of Oregon; Jill Karsten and Lisa Rom/NSF; Marlene Kaplan/NOAA; and Heather Mannix/Consortium for Ocean Leadership for their contributions during a number of ORAP work sessions.