Oregon State University: College of Oceanic & Atmospheric Sciences

Ocean Science in The SMILE Program: Combining Ocean Literacy and Concept Mapping as an Aid for Curriculum Development

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Abstract

This study reports on the creation and testing of a model concept-mapping process that will aid the development and documentation of ocean science educational content of The Science and Math Investigative Learning Experiences (SMILE) Program, a pre-college science and math enrichment program based at Oregon State University. The project uses the professional knowledge of SMILE high school teachers and staff to pilot a curriculum development process. This process highlights one of the seven Essential Principles of Ocean Literacy to produce ideas for educational activities that will facilitate learning of that principle by students in SMILE after school clubs. Specifically, participants generate activity topics linked to the ocean literacy principle by producing concept maps of the underlying fundamental concepts of that principle. The concept-mapping process collaboratively identifies 12 specific themes that should be included in SMILE ocean science curriculum to enable students to fully comprehend the chosen principle. Semi-structured interviews with key informants found that support for the future application of the process is positive, but requires modification to make it a) part of regular programming, b) more time efficient and c) more directly applicable to other informal education settings. This study also bridges the gap between the curriculum that SMILE provides to it's after school clubs and teacher professional recommendations on what should be included in this curriculum.

Introduction

Ocean Literacy is the concept of developing an ocean literate society; increasing national ocean stewardship and emphasizing the need to better educate people about the interdependence between humans and the ocean. Two recent governmental reports on ocean policy have recognized the need to improve ocean literacy efforts, highlighting the importance of an engaged public in ocean issues and calling for "a new era of ocean literacy that links people to the marine environment" (U.S Commission on Ocean Policy, 2004; Pew Oceans Commission, 2004). One response to this need has been the creation of the Essential Principles and Fundamental Concepts of Ocean Literacy, or the ocean literacy principles (OLPs). Developed in 2005 by the Centers for Ocean Science Education Excellence (COSEE) as a collaborative project between organizations such as the National Science Foundation (NSF), National Geographic Society, and the National Oceanic and Atmospheric Administration (NOAA, through Sea Grant), the OLPs (Appendix I) provide a framework for both formal and informal K-12 educational activities. In line with this framework, an ocean literate person

1. understands the OLPs about the functioning of the ocean,

2. can communicate about the ocean in a meaningful way,
3. is able to make informed and responsible decisions regarding the ocean and its resources (Cava *et al*, 2005).

Ocean literacy is used to not only build upon the efforts to better define the OLPs, but to also assess what the public knows about the ocean, and address the lack of related content in state and national science education standards, instructional materials and assessments (Schoedinger *et al*, 2004). In the wake of national interest in ocean literacy, informal science education institutions have embraced the ocean literacy movement on a variety of levels as a guide to developing materials, allowing the OLPs to hold much potential for science learning, assessment and evaluation.

The term “literacy” in the context of this study can be defined in two ways: on the one hand it is simply the knowledge required to understand the ocean sciences; on the other it is the ability to *do* something with that knowledge. The ability to do something with scientific knowledge is a major component of hands-on or inquiry-based learning often associated with informal education environments, enabling a learner to construct their own meaning and knowledge, therefore increasing long-term and sustained interest (Falk & Dierking, 2000; Gibson & Chase, 2002). Despite the OLPs attempt to address both definitions of literacy, the current format is mostly concerned with the knowledge itself, creating limitations to its application particularly in the informal environment. This is exemplified in the OLP’s construction (Ocean Literacy Network, 2009), which explicitly numbers each principle (inferring hierarchy), lists only conceptual statements and provides cross-reference to only formal education matrixes. In order for the OLPs to promote true environmental literacy for the ocean sciences, (i.e., a combination of awareness and personal conduct relative to that awareness (Coyle, 2005)) their format must be able to transition from the brochure page to inquiry-based methods for both the formal and informal education setting. This can then in turn promote a more ocean literate life-long learner, i.e. one that can make more informed decisions regarding the ocean both now and in the future.

Concept maps are a research and evaluation tool well established in formal education settings, yet relatively new to informal settings (Falk, Moussouri & Coulson, 1998). Participants create web-like diagrams of relationships around a central theme, graphically representing their understanding of that topic. The resulting maps may then be used for self-assessment or group assessment of learning to make knowledge visible and sharable (Harvard Project Zero, 2009), to brainstorm, or to document preconceptions, misconceptions and general knowledge of the topic before and after a particular learning experience (Christensen, 2007). In relevance to curriculum development, this project began on the premise that this process of mapping meaningful relationships between concepts could also provide a useful method of elaborating on the OLPs for more practical applications. Both Edmonson (1993) & Vilela *et al* (2004) discuss concept mapping as an effective tool for collaborative curriculum development, describing "the construction of the map [as] a powerful tool in the visualization of the demands of curricular reform". Vilela *et al* (2004) also note the ability of such mapping to identify not only relationships between concepts, but also gaps in proposed curriculum. Integrating concept mapping into the ocean literacy framework therefore holds the potential to produce central topics around the OLPs and create a useful process for not only establishing new ocean science curriculum, but also in highlighting gaps in the existing curriculum and making new connections to past curriculum, important factors in increasing student conceptual connections to other science topics.

As an attempt to address the issue of involving ocean literacy in regular informal programming, the aim of this study is to use the OLPs to create a model ocean science curriculum development process for The Science & Math Investigative Learning Experiences (SMILE) Program. The SMILE Program is an education and outreach program based at Oregon State University (OSU), which uses ocean science as a focus for its 9-12 grade after school club materials. A new curriculum development process that combines concept mapping with ocean literacy can enable SMILE to collaboratively identify key learning topics/themes that will aid the program in developing materials based on the OLPs. The outcomes of utilizing such a process can not only help to increase ocean literacy for Oregon students involved with The SMILE Program, but also provide a better understanding of the level to which the program itself communicates particular OLPs. SMILE can benefit from the application of this process by identifying gaps in current curriculum, showing where the curriculum is strong, and making connections between past, present and future curriculum for planners, teachers and students alike. The study provides a basis for future curriculum evaluation methods involving the OLPs and perhaps can assist other informal science educators and/or programs in developing curriculum that best incorporates ocean literacy or other science content benchmarks, standards or frameworks.

Research Questions & Objectives

Two questions provide the basis of this study:

- How effective is a concept-mapping process based on the OLPs at developing educational topics and ideas for The SMILE Program relative to ocean literacy?
- Would this process be a viable system to incorporate into The SMILE Program planning, as well as for other informal education settings?

Working with SMILE professional staff, four research objectives were developed in order to answer the above questions:

1. Create a concept-mapping process that involves SMILE high school club advisors in developing future ocean science curriculum.

2. Identify key focus topics that effectively communicate and aid the understanding of one example OLP using this process.
3. Identify strengths and weaknesses of the concept-mapping process for The SMILE Program and other informal education settings.
4. Provide recommendations for incorporating the use of this process in future ocean science programming for The SMILE Program and in other informal education settings.

The concept-mapping process was pilot tested with SMILE club advisors (teachers) during winter 2009 and with SMILE professional staff during spring 2009. Semi-structured interviews, centered on test outcomes and future application, were also conducted with current and former SMILE staff in spring 2009.

Background

The SMILE Program

The SMILE program is a partnership between OSU and 14 Oregon school districts, serving as a pre-college science and math enrichment program for over 650 elementary, middle, and high school students in rural areas throughout Oregon (The SMILE Program, 2009). The program conducts a year-round schedule of activities designed to provide hands-on science experience, strengthen student knowledge and raise student academic and career aspirations (The SMILE Program, 2008) via elementary, middle and high school after school clubs in each of 35 SMILE-partnered schools. Each SMILE club is led and instructed by at least one club advisor; a current teacher actively based at the particular school where the club is located. Ocean science is primarily incorporated into the high school level programming, where there are currently 20 active high school teachers serving as club advisors in 11 SMILE-partnered high schools, all key in communicating ocean science content to 9-12 grade SMILE students. Figure 1 shows the distribution of these sites.

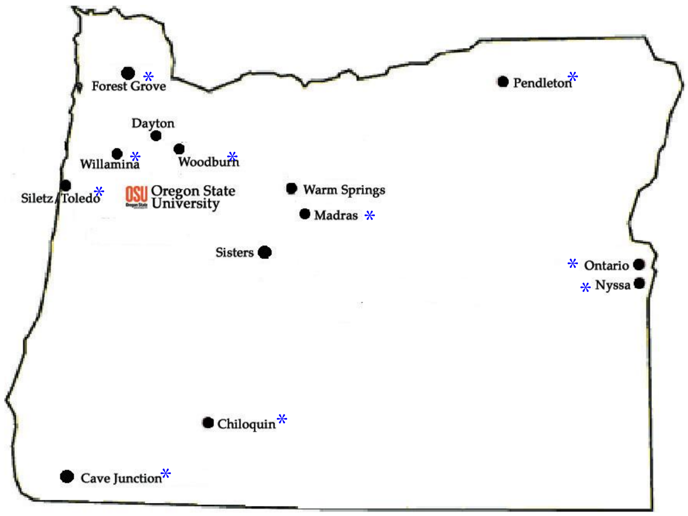

*Figure 1: SMILE community locations across Oregon, those marked with * indicate communities with high school clubs* (The SMILE Program, 2008)

Science and math curriculum, plus science experiences, are provided to the club advisors during professional development workshops (PDWs) held 3 times per year. Both summer and winter PDWs are held on the OSU campus, whilst the spring PDW is held at a retreat location in Oregon that varies annually. These PDWs are designed to connect the advisors with OSU researchers, widen their professional knowledge base and, specifically for the high school advisors, increase their own ocean science comprehension and therefore quality and quantity of outreach activities through the clubs. As club advisors adapt SMILE curriculum to suit the needs of their students, SMILE PDWs involve a variety of interactive learning sessions and talks that promote inquiry-based science learning while simultaneously exposing advisors to science expertise, knowledge and current research that they may not encounter in their daily activities as a public school teacher or during personal free choice learning. PDWs have an important and documented role in continuing to build upon SMILE's community of practice (Bottoms, 2007), and, since SMILE communities are spread out across Oregon, are essentially the only opportunities to connect with numerous club advisors as a whole group.

Since 2004, The SMILE Program has held a successful partnership with the Cooperative Institute for Oceanographic Satellite Studies (CIOSS) and the Center for Coastal Margin Observation and Prediction (CMOP) to provide club advisors with ocean science professional development and ocean science curriculum. These scientific groups have an interest in education and outreach for which they partner with SMILE, specifically funding the annual SMILE high school challenge event. Each spring, the high school clubs gather together to engage in an overnight team challenge event which connects high school SMILE students with the university environment and provides science enrichment activities centered on an ocean-science based problem. A different overarching ocean science theme is chosen each year as a focus of the high school challenge, and 10-12 prerequisite units of curriculum are subsequently developed annually to prepare the students for the challenge event. The overarching theme has been a number of ocean science topics to date (including fisheries management, ocean rescue and tsunamis), most of which illustrate a connection between humans and the ocean (Dover, 2008). Figures 2 and 3 describe how ocean science content is delivered to students through the SMILE-scientist partnerships.

Position	Description/Role	Location
SMILE Assistant Director of Programming	Supervision of ocean science curriculum development/professional development activities	SMILE office (OSU)
SMILE Graduate Research Assistant (GRA)	Graduate student coordinator of high school challenge event and main ocean sciences curriculum developer	SMILE office (OSU)
SMILE Program Coordinators	University staff at SMILE who advise and assist GRA curriculum developer role	SMILE office (OSU)
SMILE high school club advisors	Teachers based at SMILE communities, who directly facilitate ocean science curriculum to SMILE student club participants	SMILE club communities across Oregon
SMILE high school students	Club participants who receive learning experiences from the ocean science curriculum and challenge event	SMILE club communities across Oregon

Figure 2: SMILE roles in ocean science curriculum development and application

Graduate Student Ocean Science Coordinator

- Appointed through CIOSS/funded by NOAA
- Designs materials for teacher workshops, science understanding and pre-challenge club activities
- Provide expertise to support marine education and ocean literacy
- Recruit partners for teacher workshops, club activities and challenge event
- Gain experience working with the SMILE program model, public school teachers and Oregon students
- Learn methods to engage students and adults alike in ocean science

Teacher Workshop & Club Preparation

- Provide ocean science-themed learning opportunities for club settings
- Involve OSU researchers/graduate students in the development and delivery of ocean science-themed club activities
- Increase teacher understanding of ocean sciences and engaging students in satellite oceanography
- Promote preparation and increase aspirations for higher education amongst high school students
- Increase student awareness of science-based careers

High School Challenge

- Provide ocean science-themed learning opportunities through an on campus challenge event
- Involve OSU researchers/graduate students in the development and delivery of ocean science problem-based scenarios
- Involve and interact college students as mentors and role models to facilitate team engagement
- Involve student teams in a problem solving process
- Team members use a variety of science expertise learnt in the club setting to address the given problem
- Teams develop new expertise related to the given problem in sessions presented by experts, faculty and graduate students
- Teams apply this knowledge to the problem, presenting their understanding in a variety of methods

Figure 3: The SMILE ocean sciences program model (Dover, 2009)

The SMILE Program conducts numerous evaluations of all aspects of its program, and at the high school level evaluation centers often on club satisfaction with the offered content and challenge event. However, to date little front-end evaluation has been conducted to involve the SMILE high school club advisors in ocean science curriculum development before the process begins. Since club advisors are key to determining the needs of the SMILE students, testing new evaluation methods is important to providing ocean science content that will effectively communicate to clubs and utilize club advisor expertise as informants about which ocean science topics may, or may not, be effective in the club setting. This kind of consulting with professional or expert knowledge grounds evaluation findings in reality, subsequently providing more reliable data (Gall *et al*, 2004). Thus, club advisor involvement in curriculum planning is vital in achieving better quality educational programming for SMILE overall.

An important aspect of the program as a whole is developing a "community of practice" (Lave & Wenger, 1991) between and among staff, club advisors, volunteers and funders. In the past, there has been a significant gap between SMILE club input and future curriculum development, since the curriculum is developed by staff at the university with scientist input but without advisor input. Bridging this gap using a collaboration with club advisors to create curriculum will not only improve SMILE's adherence to its own goals as a program, but also the educational leadership training and professional growth it provides, allowing the club advisors to more effectively transfer science skills to the classroom and club setting (Bottoms, 2007; Joyce & Showers, 2002). Effective reform efforts in science education depend on the practical knowledge of teachers (Driel *et al*, 2001). Thus, the more the club advisors are involved in the SMILE curriculum development process, the better the quality of ocean science content will be overall, and the more consistent The SMILE Program model will be with its own stated goals and science education reform efforts broadly conceived.

Concept Mapping in Informal Science Education

Concept mapping is a visible thinking tool related to constructivist ideas of learning that promotes group planning and thinking processes. Essentially, concept maps are graphical representations of a participant's personal cognitive linkages to a central concept (Novak, 1990) and have long been an effective and valid tool for evaluation of student learning and conceptual knowledge change for formal science education settings (Markham, *et al*, 1994). Concept mapping in informal science education is becoming more widespread, having been recognized as a creative tool appropriate for the variety of analyses necessary in informal learning environments (Rennie, *et al*, 2003). Examples of its applications include evaluating cognitive constructs of learners before and after a particular learning experience, as well as assessing learner expectations, misconceptions and perceptions about particular topics or themes (Christensen *et al*, 2007; Nickels, 2008; Rollins, 2007; Falk, Moussouri & Coulson, 1998). Additionally, concept maps, as well as their derivatives (e.g. personal meaning mapping), have been used to provide insight into visitor learning from exhibits in museums and science centers (Falk & Storksdieck, 2003), as well as to determine the level of influence school visits to informal settings have on formal learning (Anderson, *et al* 2000). It is clear concept mapping as a tool is both valid and appropriate for the complexities involved in informal education research and evaluation, and that it may also be useful for research into programs such as SMILE that create bridges between formal and informal science learning. However, little research exists on the ability of concept mapping to aid informal curriculum development. Drawing on concept mapping's strength to create diagrams of conceptual linkages and their accessibility to participants, data collection involving concept mapping is an important focus for this project.

For the purpose of this study, concept mapping remains an evaluative tool, drawing on the cognitive perception and opinion of a professional group, rather than representing the knowledge of particular individuals. The goal is to attempt to form and document consensus on learning topics, activities and vocabulary necessary to invoke ocean science conceptual understanding for high school students. The use of concept mapping is relatively new to The SMILE Program. Concept mapping has only been used in the past to initiate conversation regarding ocean literacy and prior club ocean science material for SMILE ocean science programming not as a front-end evaluation process.

Ocean Literacy & SMILE

Other than the relationship to the annual overarching challenge theme, high school club materials provided by SMILE are not developed with any specific standards or educational frameworks in mind, making SMILE curriculum development sometimes sporadic or unstructured in nature. Unstructured content may be a concern for The SMILE program, as SMILE curriculum is rarely repeated, unlike other informal programming that may use the same curriculum repeatedly. Specifically, this means that SMILE may not be able to evaluate a given curriculum's effectiveness or engagement with students, something that is often easier to do when a curriculum is constantly repeated. Therefore new SMILE curriculum may benefit from some acknowledgement of a framework both by providing a structure for ocean science content and improving the clarity of program or activity objectives before facilitation: a necessary step when curriculum is associated with "once off" learning experiences. In light of this, one suggestion for an addition of a framework to SMILE's curriculum development process may be through the adoption of formal science education standards. However, as ocean science is severely lacking in state and national science education standards (Steel *et al*, 2005), and informal learning environments differ greatly from formal education in their approaches to curriculum, it is somewhat inappropriate to state or national standards as a starting point. Another solution that underlies this work and is potentially more in keeping with the spirit, goals and structure of an informal educational experience like SMILE may be the utilization of ocean literacy, and more specifically the OLPs. At this point, it is important to note the definition of curriculum, which is different in informal settings. For the purposes of this study, curriculum is viewed in a broad sense, and refers to subject areas and plans for inquiry activities rather than defined/outlined lesson plans. Although SMILE programming both develops and makes use of lesson plans, there are a number of steps that would be required in order to inform specific lesson plans. Thus this front-end work focuses on topics related to overarching OLPs and the annual challenge themes and activity themes that emerge from them.

At the time of this project, the OLPs are also incomplete due to their inability to provide more specific ideas for curricular topics or materials. Strang *et al* (2007) illustrate the importance of ocean literacy in science understanding as a whole and highlight the need to produce an inventory of curricular materials cross-referenced to the OLPs. In this regard, SMILE high school programming could become a model for informal ocean science curriculum development, as well as promote curriculum that supports a greater general science understanding for students. The ocean literacy framework may be more effective for future marine education curriculum planning in a way that is similar to the use of environmental literacy within environmental education programs (Stables, 1998). Additionally, the integration of the ocean literacy framework will ultimately enable SMILE to begin to track their ocean science content over time, a useful component not only for program evaluation, but also for pursuing current and future funding.

This investigation combines the OLPs and concept mapping to create a new curriculum development process for The SMILE Program, piloting this process as a model for using ocean literacy in program planning for both SMILE and other informal science education settings. Such settings, including The SMILE Program, value their ability to present high quality science that is more exciting, approachable and appropriate for their audiences. Thus, the incorporation of the ocean literacy framework into this process is designed to maintain this flexibility whilst improving ocean science content structure. This process is valuable to programs such as SMILE who wish to integrate the OLPs better into their curriculum development, and is intended as the front-end step to the idea of creating curricular themes centered on desired OLPs overall. It is also intended to be worked on by different members of a community of practice at different points, i.e. back-checking themes/topics between SMILE staff and club advisors, in order to increase collaborative effort and assimilate ideas on ocean literacy. It is hoped the study will provide SMILE, as well other informal settings, with the opportunity to embrace more universal standards, such as ocean literacy, without giving up the freedom to create curriculum that makes them unique from formal settings. Additionally, this project allows SMILE club advisors to provide input for the curriculum materials they are involved with, improving the ability of these key informants to integrate ocean science materials into their own teaching interests and styles, as well as their personal relationship with the ocean science content itself. This is important in providing quality professional development that can subsequently increase ocean literacy among facilitators.

Methodology

Participants

The primary participants in this study were 13 teachers who currently serve as high school level SMILE after school club advisors, representing 65% of the total number of high school club advisors and 9 of the 11 SMILE-partnered high schools in Oregon. The club advisor participants were chosen based on their experience with SMILE ocean science content, familiarity with the needs of their SMILE clubs and professional knowledge applicable to educational curriculum development. Together these advisors have an average of 8 years of experience and service with The SMILE Program. All of them have been involved with the CIOSS/CMOP-funded ocean science content at some point since its integration into SMILE high school programming in 2004.

Four SMILE Program staff, representing program coordination and direction at different levels, were also invited to repeat the pilot test procedure. Additionally, 2 of these staff participants were involved in a series of semi-structured interviews, as was 1 former SMILE staff member who now represents Saturday Academy, another informal pre-college science program at OSU. Interviewees were chosen based on their familiarity with The SMILE Program, informal science education curriculum and ocean literacy.

Past Data

Past evaluation data on ocean literacy was obtained from The SMILE Program and used to determine which of the 7 OLPs would be most effective to use as part of this test of the model curriculum development process. This data showed that OLP # 6, “the ocean and humans are inextricably interconnected”, had the most extensive coverage over the past four years and thus it was chosen as the test OLP. This was a positive reflection of the SMILE high school ocean science programming, which focuses on real world and community based scenarios for its annual challenge theme. The past data, in the form of concept maps, described how club ocean science curriculum has correlated with the Ocean Literacy framework since its integration in 2004 and was collected from a focus-group study conducted with SMILE high school club advisors during a PDW held in August 2008 (example concept map, appendix II).

One OLP was chosen because it seemed unsuitable at this stage of testing to use all OLPs due to the extent of time and effort that would be required of the club advisors to map all the underlying concepts of all seven OLPs. Such commitment would not likely be favored by either the advisors or The SMILE Program itself since the process was folded into the winter PDW and a longer time commitment would have taken away significantly from the other professional development and science learning opportunities of the PDW. Additionally, the strong correlation of prior SMILE ocean science content with OLP # 6 allows the researcher to make direct connections for the club advisors between this new process and familiar content, a key feature of constructivist teaching and learning.

The sample OLP helps develop an overarching model that better defines The SMILE Program's use of the OLPs and provides a starting point for an entire curriculum structured with ocean literacy. Extensions from this research would fully realize the entire model (i.e. all OLPs) and include broader audiences, such as funders and club participants, as well as those outside The SMILE Program itself in the process.

OLP Curriculum Development Process

The new curriculum development process was designed to integrate the OLPs with concept mapping and enable group collaboration on ocean science topics that would best develop student understanding of a sample OLP through that OLP's underlying fundamental concepts. The first four (of a total seven) underlying concepts of the sample OLP were chosen as pilot concepts for participants to map:

a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and nearly all Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also important in the heritage of many cultures.
d. Much of the world's population live in coastal areas (Ocean Literacy Network, 2009).

Appendix III highlights a sample map produced with concept d from above.

Data Collection

All high school club advisors present at the SMILE winter PDW on January 30th 2009 participated in the pilot test of the OLP curriculum development process. Participants produced concept maps of the underlying fundamental concepts of the sample OLP in small groups of 3-4 people. Groups of participants were instructed to collaboratively produce 4 maps of fundamental concepts a through d, essentially "brainstorming" educational topics, activities and vocabulary necessary to develop student understanding about each fundamental concept, and subsequently the sample OLP. All participants were provided with a brief training by the researcher on how to complete a concept map for the test, using an example map stating "topics that could help teach high school students although the ocean is large, it is finite and resources are limited", an adaptation of a fundamental concept from OLP # 1 (appendix III). Each group was assigned approximately 45 minutes to complete all four maps. This process was then repeated at a later date with the group of current SMILE staff members, producing a total of 16 club advisor maps (4 per fundamental concept) and 4 SMILE staff maps (1 per fundamental concept). The process was repeated with the SMILE staff so as to not only investigate any differences in curriculum ideas that may lie between them and the club advisors, but also to provide them with a basic training in the mapping process for any future SMILE applications of the OLP process itself. Appendix IV illustrates a sample of concept maps produced from the data collection session.

Data Analysis & Outcomes

Map Coding

In order to investigate research question 1, the concept maps produced by the groups of club advisors and SMILE staff were coded in four stages: Topics, activities, scientific vocabulary and map construction.

Maps were coded for incidences of suggested topics, activities and science vocabulary mentioned by the participants, as well as explored for differences in map construction (a general measure of complexity (Christensen, 2007). Immediately a strong similarity with map structure was apparent between the maps, showing 80% of all maps were concept or hierarchal-type, or in other words primary level concepts drawn outwards from the central concept with secondary level ideas stemming from the primary (exemplified by figure 4). Hierarchical maps represent higher-order conceptual structuring associated with expertise (Vygtosky, 1986). This was expected given the professional background of all participants; educators being most familiar with secondary concepts underlying an overarching theme for class units.

Topics were coded as incidences where the participant group had identified primary topics or keywords from the central fundamental concept. Some of these topics were repeating (i.e. those that were already identified in the fundamental concepts themselves) and some were emergent (i.e. those topics that were not part of the original formulation, but were added by participants). Examples included "energy resources" (repeating) and "water cycle" (emergent). Topics also included the incidence of *subtopics*, which were essentially secondary topics underlying a primary.

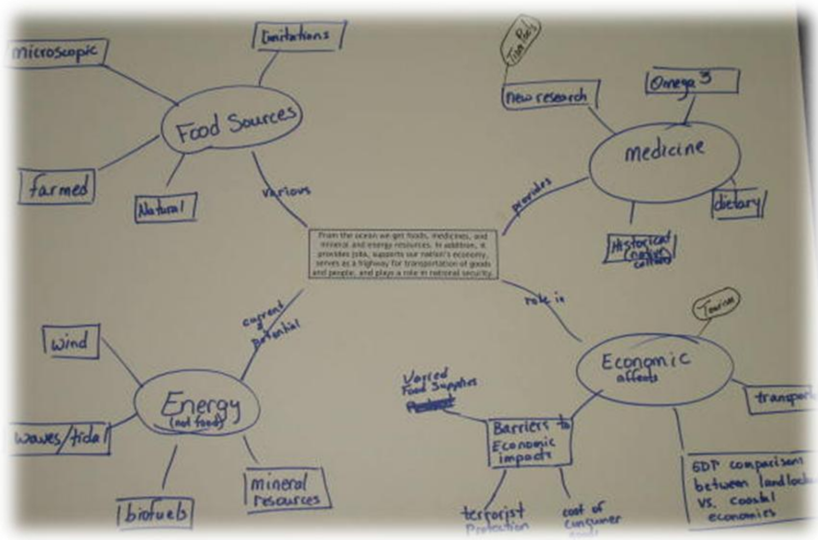

Figure 4: Example of a concept or hierarchal-type concept map. Group has identified key primary topics associated with the central fundamental concept, with underlying subtopics.

Activities were coded as a specific example of how a topic could be instructed to students, such as “field trip to a water treatment plant” or “mapping dead zones”. *Scientific Vocabulary* was coded into dual categories: “most” and “somewhat”-type scientific language as per Rollins’ (2007) categorization of scientific language in concept maps. This type of vocabulary is essentially the type of scientific language not used in everyday discourse (Gee, 2001; Rowe, 2002), and that may be integral to the instruction of identified topics. Examples included “phytoplankton” and “ocean acidification”. Some incidences of topics, activities and scientific vocabulary were found across numerous maps, thus the frequency of each incidence was also recorded (see figure 6).

<u>2: Coding categories/themes</u>

As expected, stage 1 found that there were overwhelmingly more topic incidences on each map than activities or scientific vocabulary. Many topic incidences occurred on more than one map, illustrating some form of consensus among topics between the participants. This consensus was explored further by the creation of 12 broader categories or themes, which were developed in relevance to the topics mentioned most often on each map (figure 5). As SMILE generally provides high school club advisors with 10-12 units of ocean science curriculum in preparation for the annual challenge event, these 12 themes were also established to highlight 12 possible curriculum units that participants felt would achieve student understanding of the sample principle. The maps were then re-coded using these themes to ascertain the level to which consensus was occurring and whether these themes were reoccurring throughout all fundamental concepts, or just particular ones (hence the level to which they applied to the sample principle as a whole).

	Categories/themes
1	Energy & mineral resources
2	Ocean arts & cultures
3	Biogeochemical cycles
4	Human populations & their impacts on oceans
5	Fisheries
6	Oceans as a food source
7	Medicines from the ocean
8	Role of oceans in national security
9	Ocean economics & industry
10	Waves, currents & beaches
11	Ocean & coastal recreation
12	Ocean influence on weather & climate

Figure 5: The 12 themes derived from the most frequently occurring topics mentioned on the concept maps (figure 6).

Most frequent topics/subtopics (subtopics are italicized)					
TOPIC	**Repeating?**	**TOTAL**	**TOPIC**	**Repeating?**	**TOTAL**
Art	N	**6**	National security	Y	**7**
Beach(es)	N	**3**	Ocean currents	N	**4**
Carbon	N	**4**	Ocean products	N	**3**
Chemistry	N	**3**	*Oil*	N	**3**
Climate	Y	**4**	Oxygen production	Y	**5**
Conservation	N	**4**	Percentage of population (in coastal areas)	Y	**4**
Culture	Y	**6**	*Photosynthesis*	N	**2**
Depletion (of resources)	N	**4**	*Poetry*	N	**2**
Economy	Y	**7**	Population distribution	N	**5**
Energy/mineral resources	Y	**8**	Port(s)	N	**3**
Fish (as a resource)	N	**4**	Recreation	Y	**6**
Fisheries	N	**3**	Rewards (of living in coastal areas)	N	**2**
Fishing industry	N	**4**	Risks (of living in coastal areas)	N	**2**
Floods	N	**2**	*Temperature*	N	**2**
Food sources	Y	**7**	*Tidal power*	N	**2**
Human impacts (on coastal areas)	N	**4**	*Tide pool*	N	**3**
Impacts (human)	N	**5**	Transportation	Y	**3**
Industry	N	**4**	Water cycle	N	**5**
Jobs (coastal)	N	**2**	*Waves*	N	**3**
Literature/writing	N	**2**	*Wave power*	N	**3**
Medicines	Y	**7**	*Weather*	Y	**5**
			Wind power	N	**3**
			TOTAL		**129**

Figure 6: Topics and subtopics found to be most frequently occurring across all maps, and which subsequently led to the development of the 12 themes (figure 5). Key topic reoccurrence such as "energy/mineral resources", "economy", "medicines", "food sources" and "art and " culture" (relative to the ocean) are found to be deemed important in student understanding of each fundamental concept.

It is also important to note here the extent to which topics and subtopics were pulled together to arrive at each of the 12 themes. As topics were the primary level of hierarchy established by participants and subtopics were secondary, it was important to create themes that reflected such a distinction. Therefore, even though the themes produced directly reflect the most frequent topics, it is important to notice the correlation of the most frequent subtopics within these themes. Example: “economy” was a particularly frequent topic, as was the subtopic “industry”. Thus, category 9 “ocean economics & industry” encompasses both and establishes industry as a subset. An exception to this topic/subtopic relationship occurred when the sum of the frequencies of similar subtopics outweighed other topics. For example, category 5 “fisheries” was created as a result of the sum of frequencies from subtopics such as “fishing industry”, “fisheries” and “fish (as a resource)”. Once the themes were established, they were matched against all frequent topics and subtopics (in terms of relevance) to test their appropriateness to the maps as a rudimentary form of validity and triangulation.

Once maps were recoded with the new themes, the frequency and percentage of each theme occurrence per map was calculated. Figure 7 illustrates these results and highlights the differences between club advisor and SMILE staff theme emergence. SMILE staff appear to see a more explicit picture of themes relative to the sample OLP’s fundamental concepts, while the club advisors deem a larger range of themes necessary to teach one of the concepts. This is useful information in that it shows a slight disconnect between SMILE staff and club advisor ideas regarding ocean science content. Such a disconnect implies that the SMILE staff may be overlooking particular topics necessary to teach a concept in the club setting, removing certain learning opportunities as well as full OLP student comprehension. This disconnect therefore supports the need to consult club advisors before producing curriculum.

Figure 7 also shows the extent to which themes are coherent across the principle as a whole. Some themes, such as “biogeochemical cycles”, are only apparent in one concept, (a), while others, such as “human populations & their impacts on oceans”, are associated with all concepts and could therefore “multi-task” each concept or be a “backbone” theme of that principle. Both club advisors and SMILE staff agree with all determinations of single-task and multi-task themes, verifying such a classification. The percentage of each theme per concept was also a useful indicator, a larger percentage implying the participants’ choice as more important theme to achieving student understanding of that concept, that theme being identified more often with one concept. Theme importance differs between club advisors and SMILE staff, indicating an additional disconnect in curriculum ideas. For example, the advisors deem “ocean influence on weather & climate” much more important than SMILE staff do within concept a.

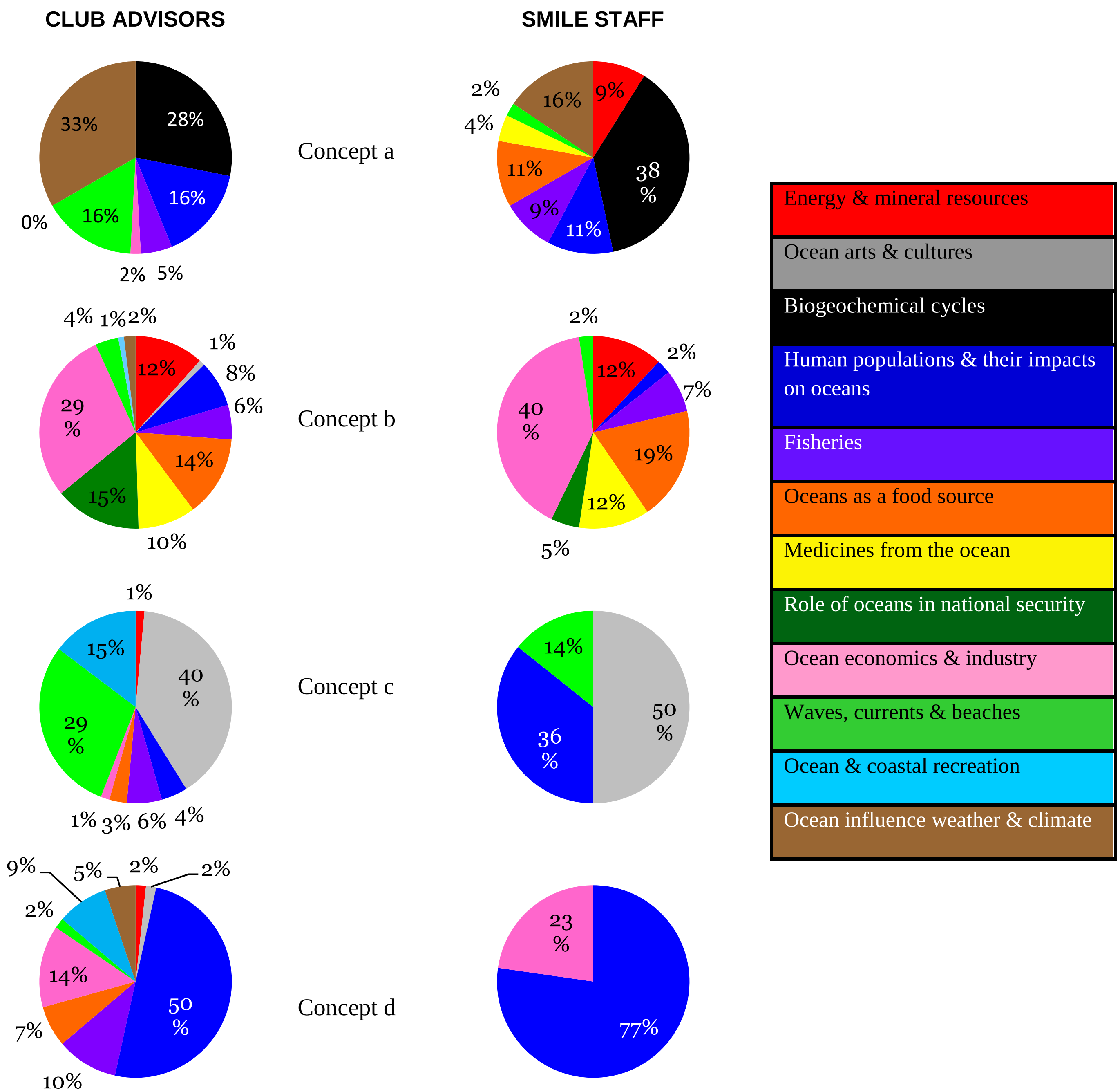

Figure 7: Breakdown of the percentage of theme occurrence between club advisor and SMILE staff maps using theme color-coding in figure 5. SMILE staff identified fundamental concepts with fewer themes than the club advisors, being more explicit about themes that teach specific concepts. Particular themes were also only apparent in particular concepts, such as "biogeochemical cycles", highlighting the ability of each theme to "multi-task" both an individual concept and the OLP as a whole.

3: Critical Connections

In order to address whether participants had noted linkages between certain themes, the last step of map analysis involved recording the frequency with which themes occurred in the presence of other themes. This is a rudimentary version of the critical connections analysis carried out by Ruiz-Primo *et al* (2009), which essentially classifies conceptual relationships between themes. For this study, themes that were found to have a greater co-occurrence with other themes were classed as "critical" in terms of their relationship to the sample OLP as a whole. The most apparent critical themes that emerged were "human population & their impact on oceans" and "ocean economics & industry", to which both club advisors and SMILE staff agreed. This is a logical outcome based on the fact that the sample OLP states "humans and the ocean are inextricably interconnected". It was interesting to find "ocean economics & industry" outweighed "human population & their impact on oceans" for critical connections, given though the latter was of primary concern in the previous stage of analysis. However, this is indicative that in terms of curriculum, both parties are able to make more connections between themes through industry examples. Three other critical themes were also identified by the club advisors; "waves, current & beaches", "ocean influence on weather & climate" and "ocean arts & cultures" (figure 8). The fact that the advisors alone identified these critical themes implies they may be more concerned with identifying thematic connections between concepts. This is consistent with the inference that they also desire a wider variety of themes, an idea mentioned above and supported by the presence of more themes per concepts in advisor maps, as seen in figure 7. It is also interesting that one of the club advisor critical themes was non-scientific (ocean arts & cultures), highlighting club advisor desire to relate ocean science to other subjects, an increasing concern of teachers in an age where science is often ignored in favor of math and literacy at all levels of public education.

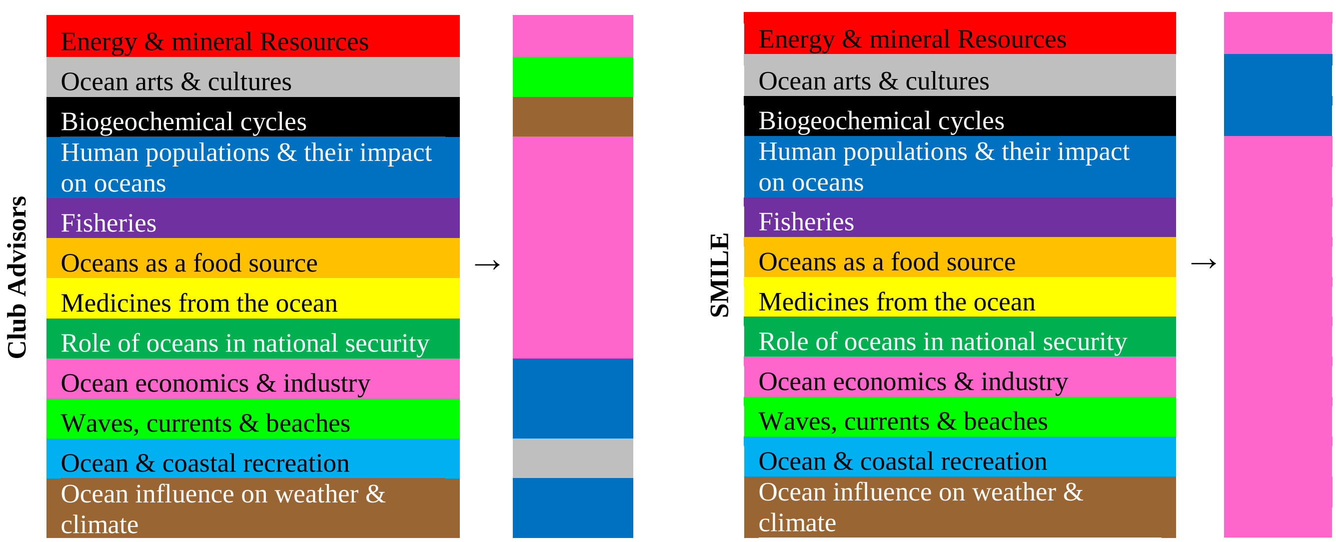

Figure 8: Most frequent theme linkages to other themes. Both club advisors and SMILE staff made more linkages to "human populations & their impact on oceans" and "ocean economics & industry" overall, but club advisors also made more linkages elsewhere highlighting their ability to see a wider variety of linkages across all concepts as a whole.

Interviews

In order to investigate research question 2, three semi-structured interviews were conducted after the concept-mapping process was pilot tested. Two of the interviewees were current SMILE program staff, the other a former SMILE staff member now working with an external informal science and engineering program, Saturday Academy. These interviews were designed to promote some informal conversation with program staff both inside and outside The SMILE Program on the potential outcomes and applications of this new OLP curriculum development process. Questions are outlined in appendix V, and figure 9 provides background information on each of the three persons interviewed.

Interviewee	M/F	Professional/educational background	Role in ocean science programming
A	M	Prof: 15 yrs with SMILE 35 yrs in environmental education Many "hobby science" interests Ed: Biology, learning theory, education	Supervises/facilitates all SMILE ocean science including PDWs, GRA hiring, creating thematic units, funders Responsible for team of coordinators who make ocean science programming happen. Created the SMILE ocean sciences high school challenge model
B	F	Prof: 6 months with SMILE Program coordination, curriculum development and teaching in marine education. Field & lab species research Ed: Zoology, marine science, marine resource management, marine education	Supporting GRA with ocean science programming Content expertise in ocean science Provides ideas/suggestions/feedback for ocean science content
C	F	Prof: 18 months with Saturday Academy 3.5 yrs with SMILE University outreach and student leadership Ed: Biology, college student services & student leadership	Supervision of numerous ocean science-related summer programs and classes Organizing high school apprenticeships in science engineering with CMOP Potential class partnerships with Hatfield Marine Science Center

Figure 9: Background information surrounding each of the three interviewees

Interview responses are summarized below and divided into four groupings:

1. Usefulness of OLP process to ocean science programming inside SMILE
2. Usefulness of OLP process to ocean science programming outside of SMILE

3. Potential barriers to using the OLP process
4. Changes/adaptations to overcome these barriers

1: Usefulness of OLP process to ocean science programming inside SMILE

Interviewee A

- Described that as SMILE creates long term partnerships with ocean science it is necessary to have conversations with club advisors for ground-truthing SMILE programming, as well as determining how SMILE can best structure ocean literacy for the club advisors to accomplish the goal of making the program more ocean literate overall. The process therefore is useful for this by design.
- Noted the process' reliability in terms of SMILE's backward design method of programming, whereby the club advisors, as key informants, can aid in more careful conversation about what SMILE is delivering to the end users (i.e. the SMILE students).
- Found the sample OLP choice interesting and very reflective of the ocean science content SMILE provides, discussing the idea that the OLPs could be reorganized to a more concept map structure so as to remove the suggestion of hierarchy (i.e. the OLP numbers 1-7). Placing the sample principle in the center is more logical as OLP # 6 is the basis for all other OLPs due to its ability to help develop personal meaning for humans to the ocean and ocean sciences, as a feature of science outreach, but also a necessary element of constructivist pedagogy.

Interviewee B

- Was particularly impressed with the process' outcomes that described differences between club advisor and SMILE staff theme priorities and how that might initiate SMILE using evaluation methods about specific content. It was also noted that such a process might encourage SMILE staff to see how club advisor ideas and knowledge of the OLPs are structured, a sort of needs-assessment that might help structure future PDWs.
- Liked the insight provided by the theme connections analysis as it can inform SMILE staff that perhaps the program can do a better job of integrating a variety of themes into ocean science content and linking those themes together
- Praised the process' ability to effectively engage the club advisors with content evaluation because it is different from the typical evaluation methods (surveys) that are used.
- Mentioned the process' compliance with SMILE's community of practice model and how it would be a great way for club advisors to share activities between clubs.
- Described how this process could be additionally valuable for SMILE's elementary and middle school clubs if other frameworks/content were included, as SMILE evaluation has not often approached club advisor opinion on content in the past

Interviewee C

- Mentioned the process as very useful for encouraging the club advisors to have more input in SMILE content.

2: Usefulness of OLP process to ocean science programming outside of SMILE

Interviewee A

- Described its ability to engage teachers with ocean science and as a positive step towards going "beyond the [OLP] brochure"

Interviewee B

- Described how the process could be very beneficial to informal education because many programs struggle with how to apply the OLPs.
- Gave the example of Oregon Coast Aquarium's "canned" marine science programs that have yet to be aligned with the OLPs and how this process could be used with education staff there, as well as with their teacher PDWs to create discussion around whether the curriculum the aquarium provides is meeting the needs of the teachers.

Interviewee C

- Shared the same enthusiasm for the process' ability to empower teachers in both the ocean sciences and developing hands-on curriculum.

3: Potential barriers to using the OLP process

Interviewee A

- Noted that the whole concept of the process could be "foreign philosophically" to other informal educators, whereby other programs outside of SMILE generally do not use external instructors (i.e. club advisors) or perhaps even backwards design to deliver programming.
- Felt the whole process seemed to be a large use of time and was unsure what would be gained if a substantial period of time at a PDW were spent using this process instead of sharing other curriculum.
- Questioned if another method could achieve the same level of conversation as the OLP process, i.e. is concept mapping one of a few methods that may be simpler?
- Expressed the concern that most informal educators are unsure and might be uncomfortable with how to facilitate concept mapping at this level, particularly with more complex data analysis methods
- Described the process as having an education-centered view, not a scientific-centered view. Thus where a program has scientists facilitating outreach, which is common in informal education, they may not feel comfortable with a more qualitative form of data common to educational research

Interviewee B

- Was concerned with SMILE's "teacher buy in" to this process considering the club advisors are already involved in much of the general program evaluation, therefore will they want to do more?
- Felt that the process as a whole was time intensive to analyze, whereby the maps themselves may be fast to code, but the data input and chart creation takes more time

Interviewee C

- Felt the process on the whole was more on the conceptual side, which may not relate well with teachers, adding that what teachers want is something practical to use in their classes and curriculum
- Was concerned with the amount of time and resources the process would take in terms of both data collection and analysis.
- Expressed that if SMILE staff required a particular outcome with the high school challenge (i.e. a theme not in the realm of the tested OLP) the process could create topics that go off in other directions, making it more difficult for planning

<u>4: Changes/adaptations to overcome these barriers</u>

Interviewee A

- Suggested the process could be made more specific by narrowing the central concept in order to gain more ideas from participants regarding activities and vocabulary, e.g. using one of the 12 produced themes and taking it apart more
- Expressed an interest in retesting the process using different methods of brainstorming/concept mapping, as an effort to "tweak" the methodology for its desired audience, i.e. if the method of collection is more liked by the participants, a clearer and more in-depth picture of ideas may be drawn
- Suggested examining how involved SMILE wants the club advisors to be in the data that they themselves produce, i.e. what are the next steps with this collected data?
- Would like to see a retest of the process with different groups who have some commonalities to SMILE, e.g. educators in a different community such as Hatfield Marine Science Center or Oregon Coast Aquarium staff. Such a retest could help make the OLPs of more utility to SMILE and help more rigorously define developed themes, particularly if this new group develops a similar list of 12 themes

Interviewee B

- Explained that the addition of this process to an annual activity with the club advisors (such as "conversations with SMILE at the spring PDW) could aid any lacking teacher buy in by making it a familiar and important component of the yearly content delivery
- Mentioned that providing the SMILE staff with more time to map could help offset their participant numbers against the club advisors (4 verses 13), thus making the SMILE staff data more accurate

- Suggested creating a summary “cheat sheet”, excel templates or additional training documents to aid SMILE or future users of the process with a complete “package”. This document/package could also be published in a newsletter or journal to make it available to other informal educators
- Had the idea that SMILE could train their current undergraduate student worker to analyze process results in the future as an attempt to reduce time commitment

Interviewee C

- Suggested making the process a regular occurrence for the program, e.g. in a PDW, and allow teachers to leave with practical ideas. This would enable a more long-term vision for the process, and help teachers see the bigger picture of why this process is important in ocean science curriculum development.
- Explained that the process should be as easy as possible for educators to use, i.e. make it “pick up and go”, as most do not have large time resources
- Recommended integrating the process into the SMILE program model itself
- As club advisors have a wide range of different backgrounds, proposed the process should allow them make use of their different skills and encourage leadership within their group, which in turn would widen club advisor input and long-term buy in
- Suggested that simplifying the process and creating step-by-step instructions could make the process more user-friendly
- Commented that the process should address why the OLPs matter and how they can fit into different teaching environments to both participants and potential users.

Overall, all interviewees were very positive toward the future application of the OLP process within The SMILE Program. This is a positive sign because it implies there is programmatic support for the process’ future incorporation into SMILE evaluation methods. The interviews support the notion that this process is appropriate for SMILE in that it relates to both their program model and community of practice. There also appears to be much scope for the process’ incorporation, both in assisting ocean science content, as well as other SMILE content.

Responses were also very positive to the application of the OLP in other informal education programs. Again this implies there is support for the use of this process elsewhere, as well as niche problems in other programs that the process could potentially aid as a solution for.

A number of issues that may impede the future application of the OLP process were described during the interviews. Interestingly, all interviews mentioned time as a limitation to the process’ application both inside and outside of SMILE, suggesting that the process as a whole is lengthy and may require shortening or simplification. Additionally, all interviews discussed the complexity of the process conceptually and that future users may find it unapproachable due to inexperience with concept mapping, suggesting any successful application of the process would at first require some more in-depth training, particularly in the data analysis, for future users including SMILE staff.

Suggestions were made by all interviewees on possible ways of improving the process so as to make its application more effective. Generally it seems that the process requires simplification or some form of user-friendly interface to both continue its application within The SMILE Program and begin being utilized in other informal settings. This indicates that although the pilot test of this process was successful, the design itself it still very much a "first draft", which was expected. Responses also suggest that in order for SMILE club advisors to be accepting of the OLP process as a form of evaluation, it needs to be incorporated into regular programming, continue to be engaging and encourage discussion and have practical outcomes that both the SMILE staff and club advisors can take away.

Summary of Outcomes

In summary, the study found:

- ✓ 12 themes, developed by both SMILE staff and club advisors, are key to student understanding of OLP # 6: "Humans and the ocean are inextricably interconnected"
- ✓ Few incidences of activities and scientific vocabulary were found across all maps, and none at all were suggested by the SMILE staff, leading to the inability to make firm conclusions about their presence.
- ✓ A consensus between SMILE staff and club advisors was identified on themes that are single or multi-task across the four concepts. Predominant single-task themes included "biogeochemical cycles" (a), "medicines from the oceans" (b) and "role of oceans in national security" (b). Multi-task themes included "human populations & their impact on oceans", "ocean economics & industry", "waves, currents & beaches" and "fisheries".
- ✓ There is a slight disconnect between SMILE staff and club advisors' ideas of themes that should be prioritized to aid student comprehension of each fundamental concept.
- ✓ "Human populations & their impact on oceans" and "ocean economics & industry" are regarded by both SMILE staff and club advisors as critical connecting themes for the sample OLP.
- ✓ Club advisors appear to see a less explicit picture of themes as belonging to individual fundamental concepts, a conclusion highlighted by their having more variety in the themes they chose per concept and overall number of critical themes.
- ✓ Support exists for the integration of the OLP process into future SMILE ocean science curriculum planning, as well as for other curriculum development; however, further testing and adaptation is necessary to validate the process and increase its efficiency as a curriculum development process.

- ✓ There is scope for the application of this process in other informal education settings, but again more testing and simplification for users is necessary.
- ✓ Both the OLP process and SMILE staff/club advisors would benefit from the process becoming part of regular evaluation, i.e. in one of the PDWs

These outcomes are a valid basis for which to not only answer the original research questions, but also provide some recommendations for future applications of the OLP curriculum development process.

Conclusions & Recommendations

Overall the pilot test of the OLP curriculum development process was successful both in the outcomes it obtained, as well as the reception it received. However, the process itself requires a number of alterations in order to make it a process suitable for repeated and future use at The SMILE Program, as well as approachable to other informal education settings.

Problems with Activities & Scientific Vocabulary

Although the OLP process was effective at producing topics, and subsequently learning themes, the process was unsuccessful at developing substantial activity suggestions and science vocabulary participants felt would aid student comprehension of each individual concept and the overarching OLP. Such activity and scientific vocabulary was lacking from the club advisor maps and not present at all within the SMILE staff maps. Possible reasons for these findings are likely related to the conceptual level at which participants were asked to map. If participants had been asked to create maps based on narrower or better-defined concepts, they may well have produced more specific ideas. Additionally, as neither the club advisors nor SMILE staff as groups are marine education "experts" and the mapping exercise was not centered on mapping knowledge, it may have been difficult for specifics such as activities and vocabulary to emerge. Time allowance for mapping may also have been a limiting factor. However, these unexpected results in no way diminish the ability of the process to be extended to all the OLPs, and can in fact help to improve the process itself. The activities and science vocabulary incidences that were found could still be categorized under the themes. Thus at this level of testing, these incidences could still be used by SMILE staff as examples of activities and vocabulary specific to individual themes. Additionally, suggestions for future application of the process from the interviews included mapping more specific central concepts, such as the themes produced, which could bring about a greater occurrence of activities and science vocabulary. The fact that the SMILE staff produced no incidences of activities or scientific vocabulary could also further support the need for SMILE to incorporate club advisors into curriculum planning. It appears the club advisors have more specific ideas of how to facilitate certain topics in the classroom setting; however more testing would be necessary to investigate this idea further.

Recommendations for the Future of the OLP Process

This study has determined that the OLP process is a viable system for aiding future SMILE ocean science content based on the mapping outcomes received and the positive reception displayed during the interviews. Additionally, the OLP process is a definite step in the right direction in making ocean literacy and the OLPs more approachable to ocean science curriculum planners for both SMILE and other informal education programs.

For SMILE, the integration of an updated or adapted form of the OLP process may be more important for the overall future of SMILE programming than originally thought. This is in light of the disconnect between SMILE staff and club advisor prioritization of learning themes that was identified in the second stage of map coding, an outcome of the pilot test that should not be overlooked. The disconnect supports the original thought that the new OLP process could have the potential to aid SMILE with incorporating club advisors into new curriculum, based on the idea that as key informants they may hold more insight into the needs of SMILE students, showing that SMILE staff ideas of necessary ocean science curriculum may be slightly imbalanced from the actual needs of their end users. Additionally, persons interviewed for this study were interested in the process' ability to evaluate curriculum within SMILE's community of practice model, supporting the idea for an addition to SMILE evaluation methods in order to better not only ocean science curriculum, but SMILE curriculum as a whole.

Interview outcomes show that the OLP would be most effective if employed as part of a regular programming event, for example the SMILE spring PDW, in order to improve both club advisor and SMILE staff comfort and with the process. Regular use could also aid in creating longitudinal evaluative data. Buy in for SMILE staff appears to already exist, yet requires further testing of the process to envision it as part of regular ocean science, or even other science, programming. Further testing would include verification of theme consensus with other groups, verification of concept mapping as the chosen evaluative method and feedback analysis from the club advisors/participants. SMILE buy in would also require the process to have a more simplified analysis methodology that would reduce the time commitment the process so far requires. This is also reflective of potential needs of other informal programs. Suggestions for these adaptations include mapping with more participants or reducing the number of maps each participant group focuses on at a time (i.e. one club advisor group per concept). Data analysis modification has also been suggested to lessen the time commitment, creating a "ready to go" package that would improve the comprehension of the process to the user and provide a step-by-step process to gain the required data. However, one might also suggest that creating such a package or template may not be suitable for use in other programs, as analysis techniques may not be generalizable. It may be more preferable for other informal programs to use a standard process for concept mapping, but combined with analysis techniques that are tailored to the needs of outside programs/projects. This may then make testing consistent, but analysis more rigorous for the setting. It is clear from the concept mapping that the process is able to produce a number of learning themes useful for curriculum planning, which can aid both SMILE staff and other educators in ocean science content as they provide central focus areas for which to create "stepping stone" units of curriculum that lead to the overarching OLP. However, these themes could be focused or narrowed more in order to create more specific activities for the high school clubs or challenge, requiring perhaps another level of mapping or evaluation. Such focus could be achieved with further concept mapping, i.e. themes of importance are "flushed out" more with SMILE club advisors at next professional development workshop to create more specific topics. This would require more planning in advance, i.e. club advisors complete this the year before the theme is required, which is reasonable given that SMILE is adept at planning annual challenge themes in advance. More focused theme mapping may also benefit other informal programs, particularly as an attempt to address current program adherence to the OLPs, or determine ideas for new classes or activities centered on a particular theme.

Recommendations for future applications of the OLP process as summarized as:

1. Retest the process to determine:
    a. Whether theme occurrence is similar with additional groups;
    b. Level of participant (i.e. club advisors) comfort with the process;
    c. Whether concept mapping (particularly in light of the time it takes for analysis) is the most effective method at producing these outcomes.
2. Develop a "next step" process for creating more focused topics for curriculum, based on required themes to satisfy desired OLP(s).Include the OLP process into regular programming, such as a PDW.
3. Summarize or simplify the testing (i.e. concept mapping) process so as to create a "ready-to-go package" (i.e. a summary document and templates) useful for future SMILE and non-SMILE users. Guidelines could be created for analysis, although these should allow flexibility for the user based on their program needs.

With modifications, it is hoped that future uptake of the OLP process will enable not only better quality ocean science programming, but also a more ocean literate SMILE community, creating the foundation for a more ocean literate population.

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Appendix I: The Essential Principles & Fundamental Concepts of Ocean Literacy (Cava *et al*, 2005; Rice, 2007)

Essential Principle	*Underlying Fundamental Concepts*
1. The Earth has one big ocean with many features	a. The ocean is the dominant physical feature on our planet Earth—covering approximately 70% of the planet's surface. There is one ocean with many ocean basins, such as the North Pacific, South Pacific, North Atlantic, South Atlantic, Indian and Arctic.
	b. An ocean basin's size, shape and features (such as islands, trenches, mid-ocean ridges, rift valleys) vary due to the movement of Earth's lithosphere plates. Earth's highest peaks, deepest valleys and flattest vast plains are all in the ocean.
	c. Throughout the ocean there is one interconnected circulation system powered by wind, tides, the force of Earth's rotation (coriolis effect), the Sun, and water density differences. The shape of the ocean basins and adjacent land masses influence the path of circulation.
	d. Sea level is the average height of the ocean relative to the land, taking into account the differences caused by tides. Sea level changes as plate tectonics cause the volume of ocean basins and the height of the land to change. It changes as ice caps on land melt or grow. It also changes as sea water expands and contracts when ocean water warms and cools.
	e. Most of Earth's water (97%) is in the ocean. Seawater has unique properties: it is saline, its freezing point is slightly lower than fresh water, its density is slightly higher, its electrical conductivity is much higher, and it is slightly basic. The salt in seawater comes from eroding land, volcanic emissions, reactions at the seafloor, and atmospheric deposition.
	f. The ocean is an integral part of the water cycle and is connected to all of the earth's water reservoirs via evaporation and precipitation processes.
	g. The ocean is connected to major lakes, watersheds and waterways because all major watersheds on Earth drain to the ocean. Rivers and streams transport nutrients, salts, sediments and pollutants from watersheds to estuaries and to the ocean.
	h. Although the ocean is large, it is finite and resources are limited.

2. The ocean and life in the ocean shape the features of Earth.	a. Many earth materials and geochemical cycles originate in the ocean. Many of the sedimentary rocks now exposed on land were formed in the ocean. Ocean life laid down the vast volume of siliceous and carbonate rocks.
	b. Sea level changes over time have expanded and contracted continental shelves, created and destroyed inland seas, and shaped the surface of land.
	c. Erosion—the wearing away of rock, soil and other biotic and abiotic earth materials—occurs in coastal areas as wind, waves, and currents in rivers and the ocean move sediments.
	d. Sand consists of tiny bits of animals, plants, rocks and minerals. Most beach sand is eroded from land sources and carried to the coast by rivers, but sand is also eroded from coastal sources by surf. Sand is redistributed by waves and coastal currents seasonally.
	e. Tectonic activity, sea level changes, and force of waves influence the physical structure and landforms of the coast.
3. The ocean is a major influence on weather & climate	a. The ocean controls weather and climate by dominating the Earth's energy, water and carbon systems.
	b. The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones.
	c. The El Niño Southern Oscillation causes important changes in global weather patterns because it changes the way heat is released to the atmosphere in the Pacific.
	d. Most rain that falls on land originally evaporated from the tropical ocean.
	e. The ocean dominates the Earth's carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere.
	f. The ocean has had, and will continue to have, a significant influence on climate change by absorbing, storing, and moving heat, carbon and water.
	g. Changes in the ocean's circulation have produced large, abrupt changes in climate during the last 50,000 years.
4. The ocean makes the Earth habitable	a. Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean.
	b. The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean.

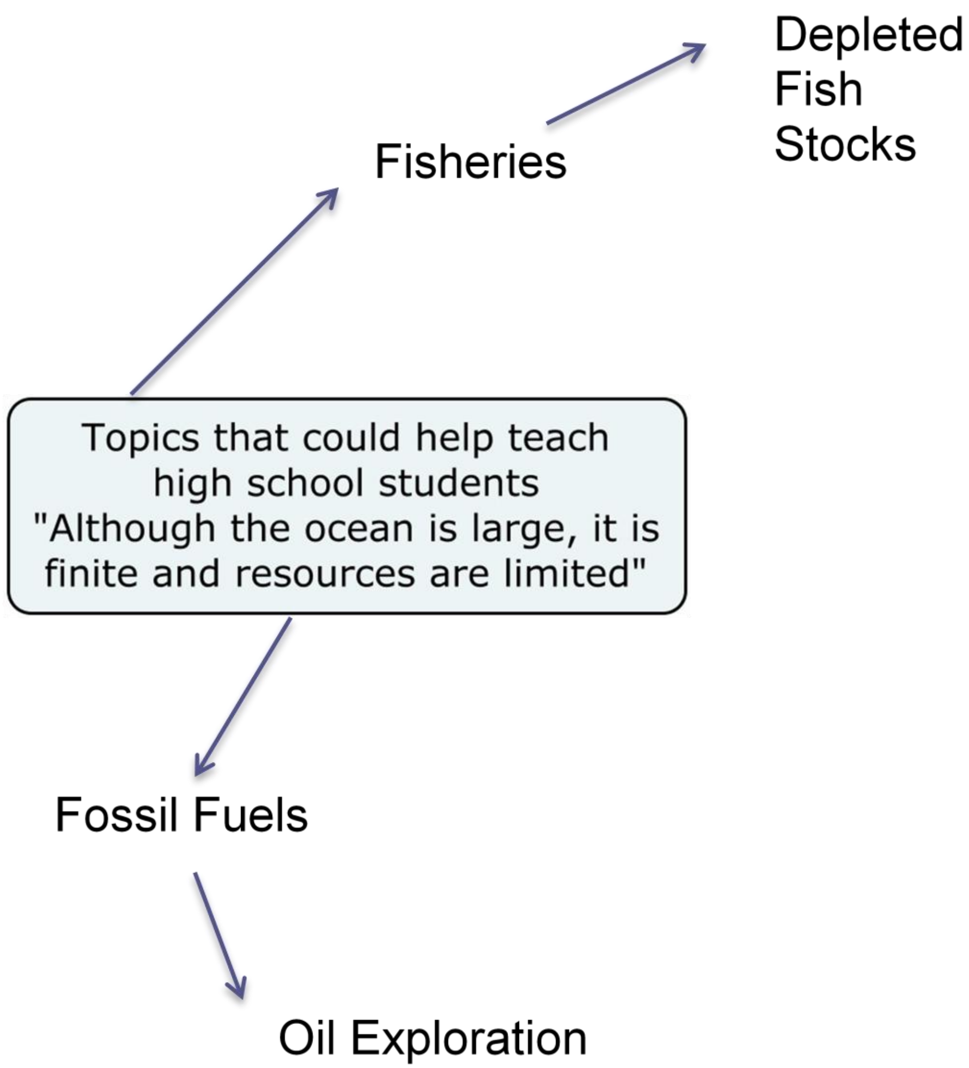
5. The ocean supports a great diversity of life and ecosystems	a. Ocean life ranges in size from the smallest virus to the largest animal that has lived on Earth, the blue whale.
	b. Most life in the ocean exists as microbes. Microbes are the most important primary producers in the ocean. Not only are they the most abundant life form in the ocean, they have extremely fast growth rates and life cycles.
	c. Some major groups are found exclusively in the ocean. The diversity of major groups of organisms is much greater

	in the ocean than on land.
	d. Ocean biology provides many unique examples of life cycles, adaptations and important relationships among organisms (such as symbiosis, predator-prey dynamics and energy transfer) that do not occur on land.
	e. The ocean is three-dimensional, offering vast living space and diverse habitats from the surface through the water column to the seafloor. Most of the living space on Earth is in the ocean.
	f. Ocean habitats are defined by environmental factors. Due to interactions of abiotic factors such as salinity, temperature, oxygen, pH, light, nutrients, pressure, substrate and circulation, ocean life is not evenly distributed temporally or spatially, i.e., it is "patchy". Some regions of the ocean support more diverse and abundant life than anywhere on Earth, while much of the ocean is considered a desert.
	g. There are deep ocean ecosystems that are independent of energy from sunlight and photosynthetic organisms. Hydrothermal vents, submarine hot springs, methane cold seeps, and whale falls rely only on chemical energy and chemosynthetic organisms to support life.
	h. Tides, waves and predation cause vertical zonation patterns along the shore, influencing the distribution and diversity of organisms.
	i. Estuaries provide important and productive nursery areas for many marine and aquatic species.

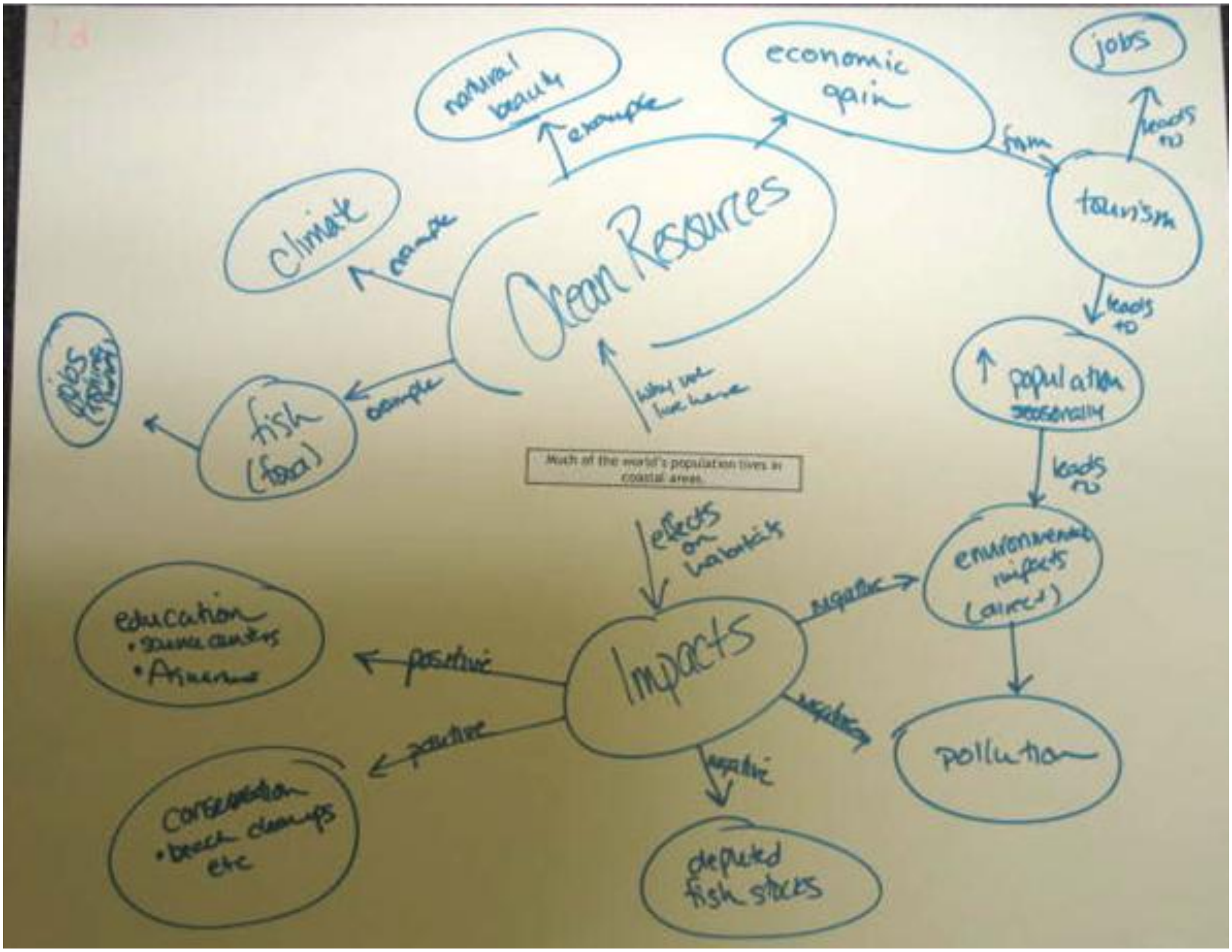
6. The ocean and humans are inextricably interconnected	a. The ocean affects every human life. It supplies freshwater (most rain comes from the ocean) and over half of Earth's oxygen. It moderates the Earth's climate, influences our weather, and affects human health.
	b. From the ocean we get foods, medicines, and mineral and energy resources. In addition, it provides jobs, supports our nation's economy, serves as a highway for transportation of goods and people, and plays a role in national security.
	c. The ocean is a source of inspiration, recreation, rejuvenation and discovery. It is also an important element in the heritage of many cultures.
	d. Much of the world's population lives in coastal areas.
	e. Humans affect the ocean in a variety of ways. Laws, regulations and resource management affect what is taken out and put into the ocean. Human development and activity leads to pollution (such as point source, non-point source, and noise pollution) and physical modifications (such as changes to beaches, shores and rivers). In addition, humans have removed most of the large vertebrates from the ocean.
	f. Coastal regions are susceptible to natural hazards (such as tsunamis, hurricanes, cyclones, sea level change, and storm surges).
	g. Everyone is responsible for caring for the ocean. The ocean sustains life on Earth and humans must live in ways that sustain the ocean. Individual and collective actions are needed to effectively manage ocean resources for all.

7. The ocean is largely unexplored	a. The ocean is the last and largest unexplored place on Earth—less than 5% of it has been explored. This is the great frontier for the next generation's explorers and researchers, where they will find great opportunities for inquiry and investigation.
	b. Understanding the ocean is more than a matter of curiosity. Exploration, inquiry and study are required to better understand ocean systems and processes.
	c. Over the last 40 years, use of ocean resources has increased significantly, therefore the future sustainability of ocean resources depends on our understanding of those resources and their potential and limitations.
	d. New technologies, sensors and tools are expanding our ability to explore the ocean. Ocean scientists are relying more and more on satellites, drifters, buoys, subsea observatories and unmanned submersibles.
	e. Use of mathematical models is now an essential part of ocean sciences. Models help us understand the complexity of the ocean and of its interaction with Earth's climate. They process observations and help describe the interactions among systems.
	f. Ocean exploration is truly interdisciplinary. It requires close collaboration among biologists, chemists, climatologists, computer programmers, engineers, geologists, meteorologists, and physicists, and new ways of thinking.

Appendix II: Sample concept map from past data collection during SMILE Summer PDW in Aug 2008.


Depleted
Fish
Stocks
Fisheries
Topics that could help teach high school students "Although the ocean is large, it is finite and resources are limited"
Fossil Fuels
Oil Exploration

Appendix IV: Sample concept map from pilot test with club advisors during SMILE Winter PDW in Jan 2009



Appendix V: Semi-structured interview questions

[Explain OLP Curriculum Development Process for The SMILE Program]

[Provide a summary of results so far]

Thank you for offering your time for this interview. The purpose of this interview is to obtain your professional opinion on a new curriculum development process based on the Essential Principles & Fundamental Concepts of Ocean Literacy that I have designed and tested for The SMILE Program. It is hoped that this process could also have applications for informal science education programs outside The SMILE Program.

1. Would you tell me a little about your background? Educational? Professional?

2. How long have you been working (did you work) at The SMILE Program? What role do (did) you play in the ocean science content development? (Do you have any ocean science related content in your current program?)

3. From what you understand about this study, do you see this process as being useful for ocean science programming both inside and outside The SMILE Program?

4. What do you think may be some barriers to using this process?

5. What would it take to overcome these barriers? Would you make any changes or adaptations?