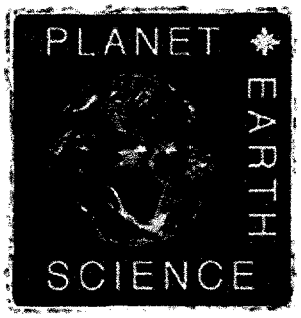

FINAL REPORT
Grant No. DE-FG03-94ER81770

- *Closeout Inventory Schedule and Certificate for Grantees*
- *DOE Final Patent Certification*
- *Final Financial Status Report*
- *Final Technical Report*

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DISCLAIMER

FINAL TECHNICAL REPORT

Abstract

During the period covered by this project we have accomplished all the objectives described in our original proposal. The main achievement, however, has been to bring to the commercial market an excellent quality education software product. This highest level of quality has been recognized by the Software Publisher Association, which has awarded its most prestigious appreciation, the Codie Award, for our first product Ocean Expeditions: El Niño.

With regards to commercialization, we have developed, as a Phase III project, a comprehensive business plan which we have used to find a publisher/distributor of our products (Tom Snyder Productions) and are presently updating to raise private funding. Also, we have been awarded a 5-year Cooperative Agreement by NASA to continue the development of our products and bring five new products to the education market by the early part of the millennium.

1 INTRODUCTION

Our DoE SBIR Phase II's objectives were to develop two science education software titles for commercialization to schools. These two titles, Ocean Expeditions: El Niño and Antarctic Expeditions: Ozone Hole have been designed to be part of a series, the Planet Earth Science Series. We have brought the Ocean Expeditions: El Niño title to market through our distributor in both Mac and PC (just recently) versions, and have developed a cross-platform version of the Antarctic Expeditions: Ozone Hole which is presently being tested in schools. In section 2, we describe the Planet Earth Science Series, including the extensive teachers' material developed. Section 3 summarizes our marketing and distribution.

2 PLANET EARTH SCIENCE SERIES

2.1 Overview

The Planet Earth Science Series represents our approach to integrating ESS into the high school curriculum. It is an interactive educational tool designed for high school science teachers to bring Earth System Science (ESS) concepts into their classrooms. This creative multimedia integrates current research activities into the classroom. This is achieved through students' use of real satellite observations of the Earth and data from climate models to study the Earth as a system of interacting components. The series further enables students to use and understand the process of scientific inquiry as an integral part of the learning process, while introducing a systems view of investigating the Earth.

Our product has two components: a game simulation in which students acting as crew members of a research vessel learn ESS concepts through interactive activities and a Teacher's material which supports the implementation of the game simulation in a science curriculum.

The software can run cross platform, that is, on a Macintosh or a PC. Both platforms feature a "smart" installer that, with a click of a button, will search and analyze the user's machine, determine all the necessary files required and perform the installation. Of course, for more advanced user's, the installer features a "custom" install that will allow the user to choose which files are installed.

2.2 El Niño and Earth system science

Ocean Expeditions: El Niño is our first product and is presented, in detail, as an example of our series and to illustrate the underlying approach and instructional principles of both the game simulation and the Teacher's Material.

The El Niño phenomenon is the strongest year-to-year climate variation and exemplifies how the ocean and atmosphere work together as a system to impact regional and global environments. It is a large-scale oscillation of the ocean-atmosphere system which has global effects on the climate and life on Earth. El Niño conditions develop in the tropical Pacific as warm surface waters invade the cold coastal waters of Peru and Ecuador. The atmosphere and ocean respond to the higher surface temperatures by altering wind, current and rainfall patterns. In the tropical Pacific, these altered climatic conditions lead to the destruction of fragile coral reefs, the decline of marine mammal populations and an increase in the number of hurricanes. El Niño takes on an even larger scope when viewed on a global scale. The El Niño signal propagates from the tropical to subtropical and mid-latitudes through the ocean and atmosphere. The relocation of tropical fish to higher latitudes, beach erosion along the west coast of North America, severe drought in Australia and excessive rainfall in Uruguay are just a few of the global effects that have been linked with El Niño.

Guided by the systems approach, *Ocean Expeditions: El Niño* investigates the interactions at the air-sea interface and the coupling between the ocean and the atmosphere. Initially, students learn about the interactions which take place at the boundary where the ocean and atmosphere meet, the air-sea interface. Students examine how the components of the air-sea interface react and respond to one another and how changes in these components impact life. After investigating the air-sea interface, students learn how the interactions which occur at the air-sea interface influence local and global circulation patterns in the ocean and atmosphere.

2.3 Students' Role and Activities

Using *Ocean Expeditions: El Niño*, students act as crew members of the Glomar research fleet. As its mission, the research crew is challenged by the "Earth Monitoring

Organization" to nowcast the state of the climate system and determine what the global consequences can be. The crew's recommendation is then submitted to world leaders who are depending on their research and understanding of the phenomenon to make economic and political decisions.

The Glomar research fleet is a fleet of virtual ships represented by networked workstations. Each research vessel is a 3D modeled and rendered ship , navigable by Apple's QuickTimeVR^{TM}. With QuickTimeVR's^{TM} 360 degree range of motion, students move about the ship as crew members and scientists, operating the ship and running the experiments. The Glomar ships provide crew members with an array of sophisticated educational tools and research equipment (Fig. 1) which help them determine the state of the climate system, namely:

- The **Navigation Table** provides students with an activity where they are guided to navigate their ship from the present location (given from a GPS) to their destination by changing the ship heading and adjusting its speed while accounting for drift due to current and wind.
- The **Communication Center** is an active part of the ship and allows crew members to receive audio and visual messages, access real time news reports and communicate with other ships in the fleet. Mission objectives are delivered to the research crew from the Chief Scientist of the Earth Monitoring Organization via the Communication Center .
- The **Instructional Center** provides the backbone for the learning experience. It contains a series of instructional modules covering the following topics: The Air-Sea Interface, Sea Surface Temperature, Ocean Surface Currents, Atmospheric Pressure, Surface Winds, Clouds and Precipitation and Coupled Ocean-Atmosphere Circulation. Each of the modules contains a series of interactive movies covering the following aspects of the topic at hand: 1) Introduction, 2) Physical Mechanisms and Characteristics, 3) Map Interpretation and 4) Patterns differences between El Niño and non-El Niño conditions. To allow students to monitor the progress of their understanding, each module provides a series of self-motivated practice and feedback sessions.
- The **Data Center** brings to life the collection and analysis of scientific data. It allows students to build maps of current climatic conditions including sea surface temperature, cloud coverage, and surface winds, among others. Maps are compiled using **real data from satellites, buoys, meteorological stations and atmospheric and oceanic computer models.**
- The **Data Archive** is an 8.5 year repository of satellite images and fields of modeled climatic variables. The Data Archive allows crew members to explore how oceanic and atmospheric conditions vary between El Niño and non-El Niño conditions. A unique feature of the archive is the "overlay" tool which allows students to study the relationship between different climatic variables. This feature is particularly conducive towards a systematic approach to science education.

2.4 Instructional Strategy

The instructional design of *Ocean Expeditions: El Niño* is based on the principles of ESS and is structured around the process of scientific inquiry. The software uses role playing as a way to ensure equal share of the computer's control but also to develop student to student instruction skills and promote collaborative learning.

As crew members venture out to complete their mission, they will follow the process of scientific inquiry. Based on observations of sea surface temperature, crew members will develop a hypothesis as to the state of the climate system. Through exploration of the Instructional Center, students will be able to explain why the El Niño signature is reflected in sea surface temperature patterns. By collecting and analyzing other data from the air-sea interface and the coupled ocean-atmosphere system, crew members will substantiate or reject their hypothesis before nowcasting the state of the climate system.

2.5 Classroom Use

Ocean Expeditions: El Niño is intuitive, simple to use, and primarily a stand-alone simulation that allows students to use it on their own and at their own pace. While students must make certain decisions while conducting their investigation, the mission itself is still highly structured; advice and direction are provided by a variety of video, audio and text messages to keep students on their investigation.

Along their mission, the student's will encounter characters as well as play roles. To master their role, student's are given a book as an aid.

The principal characters participating in the mission investigation are:

- Students: hired hands who play the following roles: Navigator, Communication Expert, Data Collector, and Data Analyst.
- Dr. Enso: Director of the Earth Monitoring Organization and scientist in charge of the expedition.
- The Captain: operator of the ship, and director of the student tasks.

While Dr. Enso directs the students' missions task by task, it is the Captain that makes sure tasks are completed.

The common role all players play is that of Earth system scientist. An Earth system scientist is a member of a team of scientists who study the interactions between the air, sea, land, snow, ice, and ecological systems. For use with smaller groups or for individual learning, students may play more than one role.

Each student is provided with a different student book, color coded by team. Each team takes one color set of books. Each team member both plays a different role (e.g. Navigator, Data Analyst, etc.) and is tasked with becoming an expert on a Sea Surface Temperature and another climate variable (e.g. Pressure, Wind, Clouds, and Currents).

By spreading the information between team members and across teams, every student becomes individually accountable for a piece of the information. Similarly, collaboration becomes imperative to advance along in the mission. Using this technique, every student takes a collaborative and active role in the mission.

2.6 Teacher Material

2.6.1 Overview

Supporting each game simulation of the Planet Earth Science Series is the Teacher Material that helps the teacher maximize the use of this game simulation and also provides guidance on how to handle Earth system science education. The rationale behind the Teacher Material is to introduce and encourage the teaching of ESS and to help introduce simulation into science. Our intent was to produce a multimedia product that introduces the teachers to this technology so that they are not hindered by technical problems and can spend their time working on Earth System Science Education.

This approach, that entirely supports the teacher, in some way revolutionizes the use of software in the classroom. It allows to give the teacher more advanced instructional material and promote self-learning on the teacher's side.

2.6.2 Content

The Teacher material is a tool containing a step-by-step teacher's guide, a curriculum integration tool, access to advanced topics, and a "Teacher's Tour", an abridged version of the game, sensitive to the time constraints of teachers. Developed in concert with teachers, the Teacher Material can be used as a quick start guide to an in depth mentoring system.

The step by step teacher's guide provides everything needed to pre-plan, implement, and assess students' attainment of key learning objectives. This is the traditional teacher's guide in an interactive multi-media format.

The Curriculum Integration tool helps to match instructional objectives with national and state science learning imperatives and the Ocean Expeditions: El Niño content objectives.

The Advanced Topics section is an on-line hyperlink textbook which offers supplementary information on scientific topics related to but not covered in the Ocean Expeditions: El Niño title. This area of the Teacher Material enables one to expand teacher's understanding of Earth System Science topics for professional development or supplementary learning activities for their students.

Finally, the Teacher's Tour provides the quickest and easiest way to step through the structure of the game, complete with video, simulators and internet related links.

2.6.3 Functionality

Functionally, the Teacher Material is best described as an Internet/CD-ROM hybrid. An Internet/CD-ROM hybrid is a product that utilizes the advantages of being connected to the Internet, such as access to real time data, with the benefits of a local, high-speed mass storage device for displaying large media files or applications with little to no download times.

The shell of the product is an interactive electronic document designed using the latest instructional strategies. Much like a lab book, or workbook, the shell contains a set of traditional instruction. Unlike traditional instruction, the shell can be enriched with embedded instructional movies, interactive practice and feedback, tutorials, or simulators. In addition to the materials custom designed for the project, the content can be extended by incorporating internet access.

This approach has several key features including:

- The core document is a very small file and can easily be updated and downloaded to keep the material fresh
- Fast access to very large files including simulators, tutorials, audio and video via a local CD-ROM
- Internet materials can readily be incorporated into design, or added later as an afterthought

2.6.4 Typical use by Teacher

The Teacher Material was designed in collaboration with many teachers. Through an analysis of the teachers' needs, it quickly became evident that the Teacher Material must offer both depth and breadth. As a result, the design reflects a structure that makes it easy for a teacher to quickly pinpoint the information that they **individually** may need.

For example, the main topics of the Teacher Material include:

- *Curriculum Integration Tool*
- *A Step by Step Teacher's Guide*
- *Advanced Topics*.
- A stand alone, interactive *Teacher's Tour* that complements the other sections.

Whereas one teacher may ask "How can I use this in my classroom to meet my state science framework?" another may simply want to know how to install and use the software. In either case, the content is organized to quickly facilitate a variety of needs.

Typically, we anticipate the Teacher Material to be used under the following scenarios: by teachers pressed for time, teachers with enough time to prepare adequately, and highly motivated teachers anxious to incorporate more integrated science into their

curricula. The following is a snapshot of how the Teacher Material may be used under the following time constraints:

2.6.4.1 Pressed for Time (1 hour)

- A Step by Step Teacher's Guide

2.6.4.2 Enough time to prepare adequately (2 hours)

- Curriculum Integration Tool
- A Step by Step Teacher's Guide
- Teacher's Tour

2.6.4.3 Highly Motivated (4 hours)

- Curriculum Integration Tool
- A Step by Step Teacher's Guide
- Teacher's Tour
- Advanced Topics
-

3 MARKETING AND DISTRIBUTION STRATEGY

3.1 Market

PES has performed a thorough market analysis for its Planet Earth Science Series. The characteristics of our market are:

- expanding financial resources to acquire products through recent federal and state funding initiatives for education software
- many decision makers (teachers but also principals, technology coordinators...)
- expanding compelling need to buy product due to directive to integrate interdisciplinary science into curricula
- products should be priced low ($50 - $100) for rapid and deep penetration of the education market
- products need to be offered and serviced by a distributor well know to the education community
- need to develop avenues to reach all segments of user's community
- product development costs need to be commensurate with sale prices
- need to have several products to provide a choice for users
- need to continuously develop products to retain customers

- need for products that support National Science Standards goals for interdisciplinary science instruction
- need educators being trained to choose products with well developed instruction and strong content base
- educators who are now more savvy at using computer based tools
- students who expect home market quality products in their educational settings
- students who are sophisticated computer users
- products which are customizable to individual district, school and classroom learning objectives

3.2 Evaluation

Planet Earth Science thoroughly tested the Ocean Expeditions: El Niño title with Jr. and Sr. High School teachers and students at all stages of design and development. Because the product, with all its components is only now complete, summative evaluation is presently being conducted but its results have not yet been analyzed.

The first aspect of our evaluation, formative evaluation, addressed revisions needed and was performed in multiple phases. This phase enlisted the help of Jr. and Sr. High School teachers in the Santa Barbara School District and ensured that the instructional objectives being taught in the program were appropriate for their curriculum needs and were consistent with National Science Standards. In addition, a treatment was presented including the likelihood students would like the use of a virtual research ship, use of characters, important consideration when developing cooperative and collaborative learning activities, on-line versus off-line record-keeping activities, etc. Four teachers were interviewed and detailed comments were recorded. As a result, the product was developed without the use of "visual characters" to limit the risk that students could not relate.

Phase two validated our interpretation of phase one findings and used the same reviewers to re-check plans for development prior to moving forward. Once agreed upon, storyboards and testing instruments were developed for a single module of instruction for testing with students. Though questions regarding "learning" were included in the tests, the true purpose of these tests was to make revisions before developing software.

Four students were pre-tested using a written pre-test of the terminal and enabling objectives, previous experience with educational software, science classes completed, and attitude toward science as a profession. Once the pre-test was complete, students, working in groups of 2, were given storyboards for a single instructional module of the Ocean Expeditions: El Niño title. Students were grouped by grade level, two 10^{th} graders, and two 12^{th} graders. There were two males and two females. Once the students had read all the storyboards, a post-test was conducted covering both instructional and

attitude objectives. Because the sample was neither randomly selected nor large enough, no quantitative test results are presented so as to mislead the evaluators.

In the next phase, teachers previously involved in the formative evaluation phase were given a complete demonstration of the software and asked to comment on the degree to which students would be motivated by the product, the appropriateness of content (level and fit with curriculum objectives), and the kind of support teachers would need to implement such a product. All comments were recorded and changes were made to the program. Comments were used to create teacher support materials which addressed both issues of "how to use the product," the fit with National Science Standards, and topics to assist teachers in understanding Earth System Science as an interdisciplinary topic.

Phase five included approximately 75 teachers, tested in two groups, who were attending a teacher training at UC Santa Barbara during the summer of '96. An extensive feedback form was completed which addressed content objectives, aspects of the multi-media including graphics, audio and video, ease of use, appropriateness of vocabulary level, and flow and degree to which teachers believed their students would be motivated by this method of instruction. Teachers were overwhelmingly impressed.

Once the CD-ROM part of the product was completed a more formal test with groups of Jr. and Sr. High School Students was conducted. The first group included six Jr. High School students; three males and three females working in teams of two at a computer. The second group included six Sr. High School students; three males and three females working in groups of two at a computer. The Jr. High School group were administered a pre-test of terminal learning objectives and then were given three 1-hour class periods in which to work. The High School students were given the same paper-based pre-test but were given two 1.5 hour periods in which to work. After the session, Mission Reports (proof of achievement of terminal learning objectives) were collected and an attitudinal instrument was administered. Test results are available but due to the instability of the product at the time of testing and the lack of random sampling and small size of the test groups, these are neither valid nor reliable results. An observation of the students and data collected from a written "how did you like it" test concluded that these groups both liked this product and would like to see more like it used in their classes.

3.3 Dissemination

Planet Earth Science is using a strategy to commercialize it products which seeks to maintain a corporate focus toward new product development while leveraging publishing agreements with the best science education software publisher in the Jr. and Sr. High school markets. The publisher is responsible for all aspects of distribution and dissemination. The rationale is that Planet Earth Science can gain credibility and thus be able to get more products to market faster with the help of an established publisher than it could do alone.

To this end, the marketing group identified all providers of Science educational software products in the U.S. Jr. and Sr. High School markets. Once all providers were

identified (approximately 100) a checklist of factors including quality of products, distribution channels, market penetration, and match with Planet Earth Science objectives was developed. This checklist was developed to ensure that the senior management team at PES concurred with the marketing department's priorities for choosing a publisher. Once agreed upon by the team, the marketing group eliminated publishers and brought a short list to the senior management team. Though, not a simple process, a group of publishers was finally chosen who were both known and respected for solid science content by our target market of teachers and who has complete access to distribution channels including science teachers, technology coordinators, and senior administrators responsible for buying educational support materials.

The marketing department then approached each of the publishers, including, Broderbund, Videodiscovery, Logal, Tom Snyder Productions, and MECC and demonstrated the product during a private meeting at the Computer Using Educators (CUE) conference in October 1996. Though all were impressed, only Tom Snyder Productions was considered the best candidate for publishing our series of products. We now have a publishing contract in place with Tom Snyder Productions. TSP supports Planet Earth Science, other than through their standard manufacturing, publishing and promotion activities, by providing feedback from customers currently using Planet Earth Science products at regular intervals and collaborating on grant writing activities for new product development, when appropriate.