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EDUCATING THE NEXT GENERATION OF SETI SCIENTISTS: VOYAGES THROUGH TIME

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ABSTRACT

The search for extraterrestrial intelligence (SETI) could succeed tomorrow, or not for many generations, or never. SETI scientists are very cognizant of the need to train the next generation of researchers who can carry on this vast scientific exploration. Previously, the SETI Institute has met this challenge by developing supplementary teachers' guides for elementary and middle schools called "Life In The Universe" and published by Teacher Ideas Press. Currently, we are engaged in a far more challenging project that is funded primarily by the National Science Foundation (NSF). The SETI Institute is creating a year long, interdisciplinary, high school science curriculum called "Voyages Through Time: Everything Evolves". We are using the theme of evolution to weave a panoramic vista for students that begins with the origin of the universe, encompasses our own origin and evolution, and looks at the evolution of technology and our possible future. By integrating different scientific and technical disciplines to explore how we answer fundamentally important questions, we hope to excite and motivate high school students with the opportunities offered by the way science is practiced today. We invite them to plan a future in which they help to enrich the answers to the big questions: Where did I come from? Where am I going? Is anybody else out there? *Voyages Through Time* consists of six modules on CD-ROMs for teachers and students that have been extensively tested both regionally and nationally. Publication is expected in 2003. The partners in the development of this curriculum are the SETI Institute, NASA Ames Research Center, California Academy of Sciences, and San Francisco State University. *Voyages Through Time* is funded by the NSF (IMD # 9730693) with additional support from NASA, Hewlett Packard Company, The Foundation for Microbiology, and the Federated Charitable Campaign. For further information, visit: http://www.seti.org/education/Welcome.html.
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INTRODUCTION

Where did I come from? What is this universe and this world that I am a part of? Is Earth the only abode for life? Are we alone?

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Adolescents and adults alike ask these questions. Studying science provides one way to probe these and related questions. Carl Sagan eloquently described our intimate relationship with the larger universe:

> "The fate of individual human beings may not now be connected in a deep way with the rest of the universe, but the matter out of which each of us is made is intimately tied to the processes that occurred immense intervals of time and enormous distances in space away from us. ...All of the rocky and metallic materials we stand on, the iron in our blood, the calcium in our teeth, the carbon in our genes were produced billions of years ago in the interiors of a red giant star. We are made of star-stuff." (*The Cosmic Connection*, pp. 189-90, 1973).

The notion that each atom in our bodies and the world we live upon was once part of a dying star ties together astronomy, geology, chemistry, and biology. Exploring this story offers a motivating framework for teaching and learning science.

Voyages Through Time has been developed as an integrated high school science course that takes evolutionary change as its main theme. Throughout the course, the same fundamental questions recur:

- What is changing?
- What is the rate of change?
- What are the mechanisms of change?

Evolutionary change underpins much scientific theory and thought: the origin of the universe and the life cycles of stars, the formation of the Earth and its oceans and continents, the origin and diversification of life, the emergence of *Homo sapiens*, and the development of scientific knowledge and technology. It is a story of epic size, capable of inspiring awe and expanding our sense of time and place. This story is the basis of *Voyages Through Time*.

The overarching goals for *Voyages Through Time* are for students to understand:

- evolution as cumulative change over time occurring in all realms of the natural world;
- the various mechanisms of these changes and their differing scales;
- the connections and relationships across these realms of change; and
- science as a process of advancing our understanding of the natural world, not a set of final answers.

The scope and potential of evolution as a theme for science curricula is widely supported. In addition to the biological and geological facets of evolution, *The National Science Education Standards*[1] and *The Benchmarks for Science Literacy*[2] both identify evolution as a major conceptual theme that extends beyond these disciplines. In the National Science Teachers Association's *The Content Core*[3], evolution is recommended as an overarching theme for an integrated high school science course.

Voyages Through Time: A Research-based, Technology-Enhanced Curriculum

Voyages Through Time is being developed to provide a one-year science course for 9th or 10th grades students. Its six modules may also be used in discipline-based science courses such as earth and space science, life science, biology and technology classes. Table 1 lists the core concepts and a sample standard/benchmark for each module.

Table 1: *Voyages Through Time*: Modules and Sample Benchmarks/Standards

Voyages Through Time Module	Sample Benchmarks/Standards
Cosmic Evolution: the origin of the universe, life cycles of stars, formation of the elements, and origin of solar systems	The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since. NSES p. 190[4]
Planetary Evolution: formation of Earth, changes in the Earth's surface, oceans, and atmosphere	Interactions among the solid earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system... NSES, pp. 189-90[5]
Origin of Life: the chemistry of life, assembly of cells, origin of multicellular life	Life on earth is thought to have begun as simple, one-celled organisms about 4 billion years ago. During the first 2 billion years, only single-celled microorganisms existed, but once cells with nuclei developed about a billion years ago, increasingly complex multicellular organisms evolved. BSL, p. 125[6]
Diversification of Life: mechanisms and events in the diversification of multicellular life	The theory of natural selection provides a scientific explanation for the history of life on earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. BSL, p. 125[7]
Hominid Evolution: mechanisms and events in the evolution of human beings	Fossil evidence is consistent with the idea that human being evolved from earlier species. BSL, p. 129[8]
Evolution of Technology: development of technology by humans and its impact on life and the planet	Science often advances with the introduction of new technologies. Solving technological problems often results in new scientific knowledge. New technologies often extend the current levels of scientific understanding and introduce new areas of research. NSES, p. 192[9]

The six modules are being published on CD-ROMs in browser-style format, a familiar look and feel for teachers and students. For the teacher, this provides a wealth of information: background science articles and references; detailed lesson plans; multi-media resources for lesson preparation and for classroom use. Each six-week module is divided into lessons and activities. All components are interlinked on the CD-ROM, so lesson and activity guides, student materials, databases, media, and selected websites can be accessed with the click of a mouse.

Each module begins with an overview for the teacher that places the module in the big picture of evolution. A background article called "The Science" plus a bibliography of books and web sites is included. As *Voyages Through Time* is a standards-based curriculum, the CD-ROM includes the grade-level standards and benchmarks. A module calendar shows the sequence of lessons and a timeline for teaching. To support planning, a "Preparation and Materials" section provides a complete list of advance preparations—such as making reservations for your school's computer lab—and materials needed in the classroom. Finally, all the media—images, animations, simulations, databases for student analysis, video clips—everything to be presented to students using a computer —are indexed for the entire module.

Voyages Through Time uses the "5 E's" instructional approach developed by the Biological Sciences Curriculum Study[10]

- **Engage**: Activities engage students' interest in the topic, identify current understandings and misconceptions, and pose questions to be addressed in the module.

- **Explore**: Activities provide first-hand experiences with phenomena that develop the concepts, processes, and skills targeted in the module; students keep written records of data, graphs, text, and sketches.

- **Explain**: Activities consolidate the prior lessons through student presentations and discussions; the teachers provide additional explanations and formal terms; students read articles and documents.

- **Elaborate**: Activities have students apply and extend ideas and skills to new examples and information; timelines of key events are constructed; students manipulate "real data" provided on CD-ROMs.

- **Evaluate**: Ongoing assessments of learning are embedded throughout the module and student self-assessment is promoted. Both performance and traditional assessments are provided for summative evaluation.

At the lesson level, interlinked sections make for easy preparation. Lessons are divided into activities that include detailed 5'Es strategies. For example, constructing a timeline is a key activity that appears in each module. In this activity, students compress the 15 billion-year history of the universe into a more familiar time scale: the 12 month calendar year. Based upon the Cosmic Calendar developed by Carl Sagan, these activities make tangible the vast time scale of cosmic evolution. In subsequent modules, more events are added to this timeline. As the course focuses on more

recent events—diversification of life, hominid evolution and the evolution of technology—the time scale is exploded into a single month, then days, hours and minutes to accommodate humans and our technology. The timelines keep the big picture before the students.

Students also use data provided on CD-ROMs for some activities. Each module includes a computerized database activity. For example, in Cosmic Evolution, students consider data about a large number of the brightest plus the nearest stars. They sort the data by various characteristics, using on-screen graphing to understand the relationship (or lack of relationship) between stellar brightness, distance, type, color, and temperature. Separately, students graph a subset of stellar data by hand to develop graphing skills. Computer-based simulations are popular with students. "What I liked best was using the CD-ROM. It was really fun because I learned how the stars move depending on the gravitational pull[11]." The purpose of these activities is for students to use a computer as a scientist does to analyze data and gain insight into natural phenomena.

Students need to read about science, too. Contemporary articles from popular science journals offer students up-to-date content as well as insights into the people and events at the forefront of science. These are on paper, not on-screen. Feedback from pilot-test classrooms indicates that additional scaffolding is needed to make the articles accessible to all students. Although students and teachers like the idea of learning from non-textbook writings, the selection of student readings is being carefully reviewed before the curriculum goes out for national field tests.

In the Community: Teaching Evolution

So, how does *Voyages Through Time* support educators in teaching evolution? First, *Voyages Through Time* offers a coherent curriculum where evolution is embedded throughout the students' learning experiences. evolution is not taught in a single chapter of the textbook to be treated briefly or conveniently ignored in the face of social and political pressures. Secondly, teachers are provided with the background resources in a special section of the CD-ROM including links to online resources to help make a confident and positive case for teaching evolution. Finally, *Voyages Through Time* demonstrates evolution as science, not as a set of beliefs. Engaging students with the tools of science and the evidence for change over time takes evolution out of the misunderstood context of a scientific belief system and places it in the correct context of a fundamental scientific theory.

Project Information:

The team developing and testing *Voyages Through Time* is comprised of practicing teachers and their students, scientists, curriculum writers, science educators, and multi-media developers. All team members have been and continue to be involved in conceptualizing, drafting, reviewing, testing, and revising. *Voyages Through Time* will be published in 2003. The project is led by Dr. Jill Tarter (PI), Jane Fisher (Project Director) and Edna DeVore (co-PI) of the SETI Institute, Dr. Yvonne Pendleton (co-PI) of NASA Ames Research Center, Dr. Margaret

Burke (co-PI) and Dr. Sam Taylor (co-PI) of the California Academy of Sciences, Dr. Kathleen O'Sullivan (co-PI) of San Francisco State University with multimedia production by Learning in Motion, and evaluation by WestEd, the Eisenhower Regional Research Laboratory. The development of *Voyages Through Time* is made possible by a major grant from the National Science Foundation (IMD # 9730693) with additional support from the Hewlett-Packard Company, the Foundation for Microbiology, and the Federated Charities Campaign, NASA's Astrobiology Institute, and Fundamental Biology at NASA Ames Research Center. For further information, please visit our web site at: http://www.seti.org

REFERENCES

1, 4, 5, 9. National Research Council. *National Science Education Standards* Washington, DC: NRC, 1996.

2, 6, 7, 8. American Association for the Advancement of Science. *Benchmarks For Science Literacy*, Oxford University Press, New York, NY, 1993.

3. National Science Teachers Association. *The Core Content.* Washington, DC: NSTA, 1992. p. 20.

10. National Academy of Sciences' *Teaching About Evolution and the Nature of Science*, Washington, DC: National Academy of Science, 1998. p. 63.

11. Madfes, Tania J. "Pilot Test Evaluation Report," (unpublished) WestEd, San Francisco, Feb. 2000.