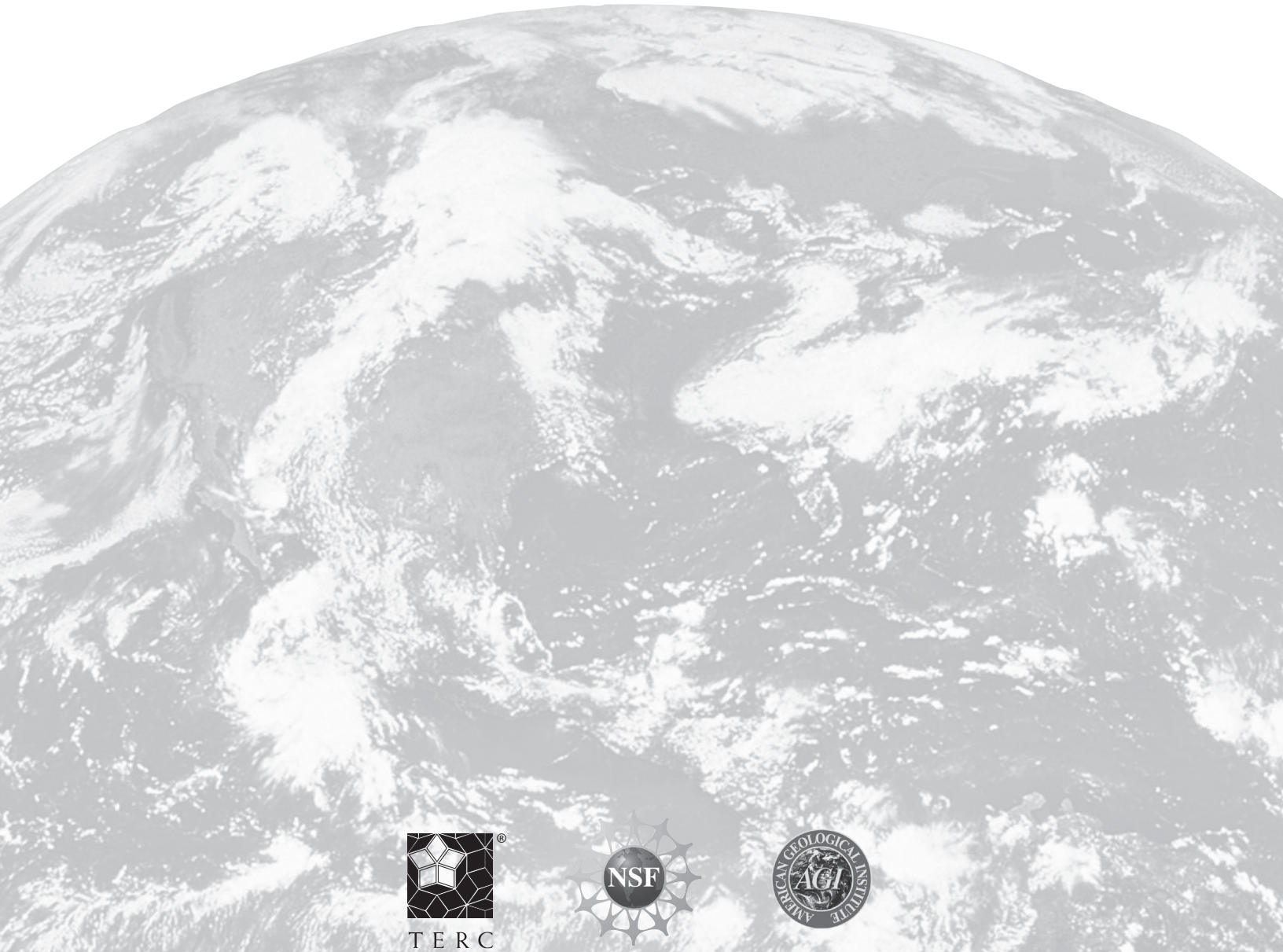
Earth Science by Design Handbook for Professional Developers

Harold McWilliams
Carla McAuliffe
Jeff Lockwood
Jamie Larsen
Tamara Ledley
Maxine Rosenberg
Matthew Hoover



TERC, Cambridge, MA
Developed with funding from the National Science Foundation

This material is based on work supported by the National Science Foundation ("NSF") under Grant Number ESI 0138644. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Printed in the United States of America.

ISBN (10) 1-929877-01-3
ISBN (13) 978-1-929877-01-0

Design and layout by
Schafer-LaCasse Design
1 Fitchburg Street C 315
Somerville, MA 02143

For updates to this *Handbook* and for additional information about *Earth Science by Design*, check www.esbd.org

For additional copies of this *Handbook* and the *ESBD DVD*, contact:

TERC
2067 Massachusetts Avenue
Cambridge, MA 02140
617-547-0430
617-349-3535 fax

Project Director and Principal Investigator
Harold McWilliams

Co-Principal Investigators
Michael J. Smith, 2001-2004
Ann Benbow, 2004-2006

Project Staff
Carla McAuliffe, Jeff Lockwood, Tamara Ledley, Jamie Larsen, Craig Warheit, Deborah Munson, Matthew Hoover, Stacey Leibowitz, Bryce Flynn, April Chuang

Consultant
Maxine Rosenberg

Teacher Co-Developers
Anne Jones, Samantha Genier, Mark Murphy

External Evaluation
Valerie Crawford and Christine Korbak, SRI International, Menlo Park, CA

Design and Production
Sandra Schafer and Bernie LaCasse, Schafer LaCasse Design, Somerville, MA

Advisory Board
Richard M. Busch, West Chester University
Anita Greenwood, University of Massachusetts, Lowell
Joseph Kerski, U.S. Geological Survey
Blanche W. Meeson, National Office for Integrated and Sustained Ocean Observations
Joseph Moran, American Meteorological Society
Eric Packenham, U.S. Department of Agriculture
Robert Richardson, Intel Corporation
Linda Shore, The Exploratorium
Grant Wiggins, Authentic Education

The Earth Science by Design program was developed with funding from the National Science Foundation, Award ESI 0138644.

Field Test Sites
Duval County Public Schools, Jacksonville, FL
Margaret Hayden, Peggy Clark, Ruth Senftleber

Jackson County Intermediate School District, Jackson, MI
Teresa Tucker, Theron Blakeslee, George Econ, Rick Collett, Matt Keeler

Missouri Botanical Garden
Bob Coulter, Rich Heuermann, Hazel Jensen, Eddie Jones, Alan Maloney

Oakland County Schools, OSM Tech Center, Waterford, MI
LaMoine Motz, Larry Sabbath, Jim Munson

Pioneer Ridge Science Center and Science Pioneers, Independence, MO
Betty Paulsell, Scott McQuerry, Jeannette Erter

Plymouth State University, Plymouth, NH
Warren C. Tomkiewicz, Mark Turski

Tucson Unified School District, Tucson, AZ
Thea Canizo, Susan Clingerman, Suzanne Maly, Alicia Nicholas, Patricia Wheeler,

San Diego County Office of Education, San Diego, CA
Nancy Taylor, Adrienne Marriott, Dave Massey

Pilot and Field Test Teachers
Cathy Adams, Terry Annicchiarico, William Arnold, Thom Baird, Jessica Epstein Baron, Rich Battaglia, Shannon Boland, Patricia Bolle, Lauren Borger, Tammy Bosom, Rosemary Brandi, Linda Brooks, Peggy Brown, Dorna Burrows, Deborah Campbell, Pia Carswell, Jeff Chambers, Christie Chiappetta, Terry Clifton, Susan Clingerman, David Clough, Sarah Coddington, Angela Comp, Brian Connelly, Gregory Cook, David Cornett, Mary Jo Crane, Jennifer Taylor Dames, Aleta Damm, Kathleen Dempsey, Cheryl Dow, Joan DuRocher, Josh Eagan, Karen Epler, Angela Epps, Elizabeth Evans-Razi, Melissa Farrell, Pamela Feffer, Mary Ann Findling, Mikie Flight-Temples, William Fox, Dawn Francis, Peggy Gasparich, Margaret Greaves, Charles Gusette, Deborah Hall, Cindy Hamilton, Michael Haritos, John Hart, Heather Hatch, Kimberly Heins, Peggy Herron, Lloyd Hilger, Deborah Hobbs, Lynn Hunt, Jeanne Hurtado, Daniel Hyliard, Marsha Irvin, Barbara Jackson, LaShell James, Amy Johnson, Vicki Jones, Jane Joyce, Thomas Kaigler, Genie Kane, Shirlee Kasztelan, William King, Fred Klafta, Deborah Kruchko, Christine Kuntz, Miranda Kurbin, Christopher Lane, Tina M. Larson, Diane Lasco, Deborah Lepper, Heidi Lyne, Jodi Mallams, Karl Mayo, Deborah McNeil, Kathleen Moburg, Steven Moore, Jody-Lee Moro, Lanny Mosley, Madge Nanney, Colby Nodurft, Sean O'Connor, Megan Ott, Joan Patton, Kate Plieth, Carol Plummer, Kathy Poe, Gwendolyn Pozdena, Marie Raftery, Jayanthi Rangan, Vince Redman, Nancy Reece, Patricia Regan, Daniel Reidy, Julie Reinhart, Rhonda Rhudy, James Rice, Zoanne Richardson, Louie Robles, Jerry Ruiz, Christine Russell, Amy Schaefer, Jody Scott, Alaina Sharp, Corey Shelton, Karen Smith, Pamela Smith, Felicia Smoot, Jerrold Snead, Lynda Summers, Susan Sumner, John Sutton, Gaylene Swenson, Laura Sylvan, Michele Tanner, Cheryl Thomas, Tina Tims, Jill Truitt, Olga Valencia-Reichert, Melissa Walts, Emily Wendt, Rebecca Widing, Dave Williams, Amanda Wilson-Koslow, and Daureen Zickerman.

Special Thanks

To Grant Wiggins and Jay McTighe for the "Understanding by Design" (UBD) approach which we draw upon for Earth Science by Design (ESBD).

To Dan Barstow, Director of TERC's Center for Science Teaching and Learning, for his work promoting the revolution in Earth and space science education and for his consistent support of ESBD.

To Marcus Milling and Christopher Keane of the American Geological Institute for their support of the project in many ways.

To Tamara Ledley, who served as our senior science advisor, and who developed the GLOBE Earth System Science Poster and learning activities which we use in Activity 6 of the summer institute.

To Valerie Crawford and Christine Korbak of SRI International, for a thoroughly professional and truly helpful evaluation of the project and the materials.

To David Libby, Director of Information Systems at TERC, for his continuing support of the project.

To Art Sussman of WestEd, author of *Dr. Art's Guide to Planet Earth* which we use as a "text" for Earth system science.

To the Harvard-Smithsonian Center for Astrophysics for their donation of *A Private Universe* which is used as a resource in Activity 14 of the summer institute.

To Sandra Schafer of Schafer LaCasse Design for her long suffering patience and unwavering professional wisdom as we edited many versions of this guide.

To our board of advisors, who have met twice to review the project's work and to provide advice. As Mike Haney, our program officer at NSF remarked after reading their first report said, "They actually took their jobs seriously."

To our NSF Program Officer, Mike Haney, for his support and encouragement.

To our field test site leaders and teachers, without whom this project could not have succeeded.

Foreword

Let's not mince words. The future of our planet depends on our ability to understand Earth as a dynamic interconnected system and to manage its resources responsibly. Humanity's ability to administer planetary resources of water and energy, deal with natural events such as hurricanes, tsunamis, droughts and floods, and cope with climate change all require a broad public understanding of how our planet works.

From energy and agriculture to manufacturing and construction, Earth and space science is at the core of billion-dollar industries that drive our economy. The procurement of energy—fossil fuels, solar, hydrogen and wind—are fundamentally rooted in Earth science. Better understanding of global wind patterns or geothermal dynamics can help us develop alternative energy sources. Better knowledge of sub-surface geology can help us tap into resources while minimizing long-term impacts. Weather and climate information is crucial to climate-sensitive industries that account for about one-third of the United States' GDP. Earth and space science is vital to our national security and emergency preparedness. Hurricane Katrina and its devastating impact exemplify the need to understand Earth's processes, better plan for the long-term, and forecast events and implement response systems.

Beyond these compelling reasons of planetary stewardship and resource management, we have the sheer appreciation of our planet's dynamics and beauty, from sinuous rivers to the vast Sahara, lush Amazon, massive Himalayas, rainbow-colored Grand Canyon, globe-spanning ocean and stark polar ice caps. The more we know about Earth, the more we enjoy our home planet and value it as a marvelous, dynamic, interconnected system. There can be little doubt that students need to understand and appreciate the Earth on which they live. They can achieve this understanding only if their teachers are well prepared.

Earth Science by Design makes a crucial contribution to improving the knowledge of our science teachers and their students, our future citizens and decision-makers. Teachers who participate in *Earth Science by Design* increase their understanding of "Earth as a system," and learn how to implement the latest approaches to inquiry-based pedagogy using web-based visualizations of Earth processes. Teachers learn by doing, by designing and teaching units of study that focus on the "big ideas" in Earth system science, then sharing, discussing and refining them with their colleagues. *Earth Science by Design* embodies the best that we know about Earth science, pedagogy and teacher professional development for long-lasting educational change. It makes an essential contribution to meeting the "grand challenge" of understanding our home planet. And just in the nick of time . . . we hope.

Dan Barstow, Director
Center for Earth and Space Science Education at TERC
Cambridge, MA

Table of Contents

Introduction

An Overview of *Earth Science by Design* xv

ESBD Program Components xvi

A Rationale for the "Earth as a System" Approach xvii

Teachers as Designers xviii

What Teachers Say About ESBD xviii

The Structure of the ESBD Program xx

Is ESBD for You? xx

Implementation Guide for Staff Developers xxi

Patterns of Teacher Change xxvii

Challenges of Implementation xxix

Earth Science by Design in the *Understanding by Design* Framework xxxi

Table of Contents

Summer Institute Guide for Developers

Days 1-10 Overview 3-12

Day 1 Schedule 13

Activity 1. Igneous Fusion: Introducing Essential Questions 14

Activity 2. Understand Me 21

Activity 3. Looking At Understanding 24

Activity 4. What is Earth Science by Design? 37

Activity 5. What is Worthy of Understanding? 41

Activity 6. An Introduction to Earth System Science 52

Day 2 Schedule 58

Activity 7. Designing an ESBD Unit: Enduring Understandings 59

Activity 8. Designing an ESBD Unit: Essential Questions 69

Activity 9. Designing an ESBD Unit: Knowledge, Skills, and Typical Misunderstandings 73

Activity 10. Introducing Assessment 78

Activity 11. Designing Performance Assessments 82

Activity 12. Creating Rubrics 88

Day 3 Schedule 98

Activity 13. Using WHERE to Promote Understanding in Earth Science 99

Activity 14. Investigating Preconceptions and Misconceptions in Earth Science .. 104

Activity 15. Visualizations and Earth Science 110

Day 4 Schedule 123

Activity 16. Applying WHERE to the Rock Cycle Unit – Part One 124

Activity 17. Applying WHERE to the Rock Cycle Unit – Part Two 127

Table of Contents

Day 5 Schedule 130

Activity 18. Continue Work on the Rock Cycle Unit in Small Groups 131

Activity 19. Using the Unit Construction Checklist 132

Activity 20. Whole-Group Review and Celebration of the Rock Cycle Sample Units 137

Activity 21. Sharing of Ideas for Units 138

Day 6 Schedule 141

Activity 22. Review of a Sample Unit: Journey to Planet Earth 142

Activity 23. Satellite Search 151

Activity 24. Assignment of Partners and Initial Work on Units 155

Day 7 Schedule 158

Activity 25. Report from the Field Video and Discussion 159

Activity 26. Check Units for Completeness of Stage 1 162

Day 8 Schedule 164

Activity 27. Challenges of Stage 2: Assessment Video and Discussion 165

Activity 28. Check Units for Completeness of Stage 2 168

Day 9 Schedule 170

Activity 29. Challenges of Stage 3: Learning Activities Video and Discussion 171

Activity 30. Check Units for Completeness of Stage 3 174

Day 10 Schedule 177

Activity 31. Teachers Meet With Mentors 178

Activity 32. Workshop Conclusion 179

Appendix A-Mentoring and Coaching Guide 182

Appendix B-Misconceptions in Earth Science by Design 187

Table of Contents

Fall Conference Guide for Developers

Overview 2

Day 1 and 2 Schedule 3

Day 1

Activity 1. Understanding How People Learn: Implications for Teaching 5

Activity 2. Tapping Into Preconceptions 8

Activity 3. Adding Earth System Science Perspective to your ESBD Units 17

Activity 4. Meet with Mentors 21

Activity 5. Visualization Roundtable 23

Day 2

Activity 6. Aiming for Deep and Enduring Understanding 27

Activity 7. Rubric Roundtable 30

Activity 8. Implementing ESBD: Conducting Partner Observations, Keeping a Reflective Journal, and Sharing Your Experiences 33

Appendix A-Sample Letter 56

Table of Contents

Spring Conference Guide for Developers

Overview 2

Day 1 and 2 Schedule 4

Day 1

Activity 1. Building Enduring Understanding in Your Classroom 6

Activity 2. Analyzing Understanding: Evidence from Pre and Post Conception Surveys 9

Activity 3: Assessing Student Learning in ESBD 11

Activity 4. Teaching Methods that Reveal Student Thinking 13

Activity 5. Sharing Implementation Results 15

Day 2

Activity 6: From Misconceptions to Enduring Understanding 16

Activity 7. ESBD and Research-Based Practice 19

Activity 8. How ESBD Has Affected Me as a Teacher and a Learner 21

Appendix A-Sample Letter 23

Table of Contents

Summer Institute Handouts

HANDOUT 1	Igneous Fusion	17
HANDOUT 2	Igneous Fusion Reflection	18
HANDOUT 3	Earth Science by Design Essential Questions	19
HANDOUT 4	The Layers of the Earth	20
HANDOUT 5	A Graph of Understanding Over Time	23
HANDOUT 6	Understanding Cube	27
HANDOUT 7	Reviewing The Six Facets of Understanding	28
HANDOUT 8	The Six Facets of Understanding	29
HANDOUT 9	Applying the Six Facets of Understanding	30
HANDOUT 10	Reflection Day 1 Morning	40
HANDOUT 11	Earth Science Concepts for "What is Worthy of Understanding?" Answer Key	43
HANDOUT 12	Earth Science Concepts for "What is Worthy of Understanding?"	45
HANDOUT 13	The Classification of Curricular Knowledge	48
HANDOUT 14	Filters for Enduring Understanding	49
HANDOUT 15	The Big Ideas in Earth and Space Science	50
HANDOUT 16	An Introduction to Earth System Science	55
HANDOUT 17	GLOBE Earth System Poster	56
HANDOUT 18	Reflection Day 1 Afternoon	57
HANDOUT 19	ESBD Unit Planner	63
HANDOUT 20	The Rock Cycle in the NSES	67
HANDOUT 21	Understandings for The Rock Cycle	68
HANDOUT 22	Characteristics of Essential Questions	71
HANDOUT 23	Essential Questions for The Rock Cycle	72
HANDOUT 24	Knowledge and Skills for The Rock Cycle	75
HANDOUT 25	Potential Misunderstandings for The Rock Cycle	76
HANDOUT 26	Reflection Day 2 Morning	77
HANDOUT 27	ESBD Six Design Filters for Assessment	81
HANDOUT 28	GRASPS Template Example	85
HANDOUT 28A	Authentic Performance Assessment Sample Vignette	86
HANDOUT 29	GRASPS Template	87
HANDOUT 30	Criterion List for Science Lab Report	91
HANDOUT 30A	Holistic Rubric for Science Lab Report	92
HANDOUT 30B	Analytic Rubric for Science Lab Report	93
HANDOUT 31	Volcanic Eruptions Rubric Construction	94
HANDOUT 31A	Assessment 1: Mystery Planet	95
HANDOUT 32	A Template for Rubric Construction	96
HANDOUT 33	Reflection Day 2 Afternoon	97
HANDOUT 34	Moon Phase Unit Preconception Survey	102
HANDOUT 34A	The WHERETO Model for Designing Stage 3	103
HANDOUT 35	Private Universe Viewing Guide	107
HANDOUT 36	Strategies to Reveal Misconceptions and Build Understanding	108
HANDOUT 37	Reflection Day 3 Morning	109
HANDOUT 38	Evaluating Visualizations	113
HANDOUT 39	Evaluating Visualizations: An Example	114
HANDOUT 40	Visualization Sets	117
HANDOUT 41	Visualization Set 1: Geosphere	118

Table of Contents

HANDOUT 42 Visualization Set 2: Hydrosphere 119
HANDOUT 43 Visualization Set 3: Atmosphere 120
HANDOUT 44 Visualization Set 4: Space Science 121
HANDOUT 45 Reflections Day 3 Afternoon 122
HANDOUT 46 Reflection Day 4 Morning 126
HANDOUT 47 Reflection Day 4 Afternoon 129
HANDOUT 48 Earth Science by Design Unit Construction Checklist 134
HANDOUT 49 Reflection Day 5 Morning 136
HANDOUT 50 Reflection Day 5 Afternoon 140
HANDOUT 51 Unit Plan–Journey to Planet Earth 144
HANDOUT 52 Satellite Search Sites 153
HANDOUT 53 Satellite Search Question Sheet 154
HANDOUT 54 Reflection Day 6 Morning 156
HANDOUT 55 Reflection Day 6 Afternoon 157
HANDOUT 56 Video Discussion Questions: Part 1 160
HANDOUT 57 Reflection Day 7 Morning 161
HANDOUT 58 Reflection Day 7 Afternoon 163
HANDOUT 59 Video Discussion Questions: Part 2 166
HANDOUT 60 Reflection Day 8 Morning 167
HANDOUT 61 Reflection Day 8 Afternoon 169
HANDOUT 62 Video Discussion Questions: Part 3 172
HANDOUT 63 Reflection Day 9 Morning 173
HANDOUT 64 Reflection Day 9 Afternoon 175
HANDOUT 65 Reflection Day 10 Morning 176
HANDOUT 66 Reflection Day 10 Afternoon 181

Fall Conference Handouts

HANDOUT 1 Discussion Questions for Chapter 2 of How People Learn: Bridging Research and Practice 7
HANDOUT 2 Preconception Survey Checklist 11
HANDOUT 3 Scientific Revolution: The Development of the Theory of Plate Tectonics: An ESBD Unit (edited) 12
HANDOUT 4 Earthquakes and Volcanoes: An ESBD Unit (edited) 14
HANDOUT 5 Global Warming: What is It and What Can We do About It? An ESBD Unit (edited) 15
HANDOUT 6 Daily Weather: An ESBD Unit (edited) 16
HANDOUT 7 Reviewing The Six Facets of Understanding - Definitions from Understanding by Design 19
HANDOUT 8 Perspective and ESBD 20
HANDOUT 9 ESBD Fall Conference Unit Checklist 22
HANDOUT 10 Visualization Sharing Guidelines: 25
HANDOUT 11 Reflection Day One 26
HANDOUT 12 Summary Sheet for "Aiming for Deep and Enduring Understanding" Activity 28
HANDOUT 13 Example Activities for the Six Facets of Understanding 29
HANDOUT 14 Volcanic Eruptions Rubric Construction 32
HANDOUT 15 Journaling for Self-Reflection 35
HANDOUT 16 Reflection Day Two 36

Table of Contents

Fall Conference Handouts-continued

HANDOUT 17 Earth Science by Design Classroom Observation Guide....37
HANDOUT 18 Earth Science by Design Classroom Observation Guide – Instructions for Partners....43
HANDOUT 19 Earth Science by Design - Example of "Running Notes" of a Classroom Session....44
HANDOUT 20 Earth Science by Design Classroom Observation Guide: Completed Sample....47
HANDOUT 21 Implementation Report Guide....53
HANDOUT 22 Spring Conference Presentation Guide....55

Spring Conference Handouts

HANDOUT 1 Discussion Questions for Building Enduring Understanding in Your Classroom....8
HANDOUT 2 Guiding Questions for Presentations on Student Understanding....10
HANDOUT 3 Discussion Questions for Assessing Student Learning in ESBD....12
HANDOUT 4 Discussion Questions for From Misconceptions to Enduring Understanding....18
HANDOUT 5 Presentation Guidelines for Panelists....20
HANDOUT 6 Discussion Question for How ESBD has Affected Me as a Teacher and a Learner....22

Introduction

An Overview of ESBD

Earth Science by Design (ESBD) is a year-long professional development program that prepares teachers to apply the principles of *Understanding by Design* (Wiggins and McTighe, 2005) to the teaching of Earth system science. With the guidance of experienced staff developers, teachers use the "backwards design" approach to organize their lessons and develop instructional units that build student understanding in ways that lead to deep and long lasting comprehension of science concepts. ESBD helps teachers bring current and relevant scientific data to their classrooms through the incorporation of visualizations and satellite imagery. ESBD is based on educational research on how students learn. Teachers learn to give careful attention to student preconceptions and misconceptions while expanding their repertoire of assessment strategies. ESBD helps teachers focus their instructional units by teaching to the "big ideas" in Earth science instead of teaching disconnected, decontextualized facts. This handbook and accompanying *Earth Science by Design* web site (www.esbd.org) provide the resources necessary for staff development specialists to offer the ESBD program to teachers in their school district or community.

When we set out four years ago to design a program of professional development for Earth science teachers that would help them teach for deeper understanding, teach to the big ideas in Earth science, teach with an "Earth as a system" approach, and use visualizations more effectively in teaching and learning it was our feeling, shared by many in the science and education community, that the "revolution" in the *practice* of Earth science was not yet reflected in the *teaching* of Earth science. In June of 2001, a national group of approximately 60 scientists and educators had met in Aspen, Colorado, for the Conference on the Revolution in Earth and Space Science Education. The report of this conference, *Blueprint for Change: Report from the National Conference on the Revolution in Earth and Space Science Education* (2002), called for professional development that helps teachers deepen their knowledge of Earth and space science, understand Earth as a system of interconnected processes, utilize the most effective pedagogy to teach and motivate students, use contemporary tools and resources such as scientific visualizations and web-based resources, and align their teaching with state and national standards. *Earth Science by Design* was created to help carry out these recommendations. (See http://www.earthscienceedrevolution.org/ for the full conference report.)

Earth Science by Design is an *empirically-tested, evidence-based* program of professional development for staff developers to implement with middle and high school science teachers. It is the culmination of four years of development, testing, and revision by TERC and the American Geological Institute (AGI), funded by the National Science Foundation. During 2004-2006 staff developers in eight sites around the country tested the program with more than one hundred teachers. We have used their experience and advice to revise and fine tune the program. This *Earth Science by Design Handbook for Staff Developers*, the *ESBD DVD,* and the web site (www.esbd.org) are the result of the project and are the tools that allow staff developers to implement the program. Although ESBD has been designed for experienced staff developers to

implement using these tools with no further training required, ESBD also offers leadership training for staff developers to help them implement the program. Consult www.esbd.org for details on training options.

This introduction provides an overview and rationale for the program, an argument that teachers should be (and are) curriculum designers, a sample of how ESBD teachers have changed and what they say about the program, a description of the structure of ESBD, suggestions about how to evaluate whether ESBD is for you, and detailed information for staff developers who choose to implement the program.

ESBD Program Components

A Year-Long Program. Consistent with national trends and research on best practices in professional development, ESBD is designed as a year-long program for a cohort of 15-25 middle or high school teachers led by a team of staff developers who work closely with the teachers throughout the school year. The program begins with a two-week Summer Institute, continues with school-year mentoring and a two-day Fall Conference, and concludes with a two-day Spring Conference. Every participating teacher designs an Earth science unit to teach, teaches the unit while keeping a reflective journal, visits the classroom of a partner teacher, and prepares a written implementation report to share with colleagues at the Spring Conference. The full benefit of the program comes from engaging teachers with ESBD in a substantial way. Teachers need to be given the opportunity to learn the ESBD pedagogical approach and apply it to their own teaching situation. It is unlikely that short in-service presentations will accomplish the goals of the ESBD program. This Handbook and the ESBD web site (www.esbd.org) provide detailed guidance for offering the program.

Based on Understanding by Design. ESBD is based on the "Understanding by Design" approach developed by Grant Wiggins and Jay McTighe. The Summer Institute introduces teachers to the UBD approach to curriculum design in a practical way. Teachers have guided practice in the creation of curriculum units of about two weeks in length. They first develop a sample unit working in teams and then design an individual unit that they teach during the following school year.

A Focus on Big Ideas. ESBD encourages teachers to teach for deep and enduring understanding of the big ideas in Earth system science. Each unit they develop is organized around one or more of these big ideas, which are based on the National Science Education Standards (NRC) and the Benchmarks for Scientific Literacy (AAAS). See the "big ideas" on http://www.esbd.org.

An Emphasis on Assessment. ESBD encourages teachers to "think like an assessor." Teachers receive instruction and practice in the development of a suite of assessments, including the design of authentic assessments in Earth science, the construction of rubrics, and the design of preconception surveys. During the Institute they review and reflect on the study of misconceptions presented in *A Private Universe*.

Introduction

An Earth Systems Approach. ESBD emphasizes the use of an Earth systems science approach. (See the recommendations of the NSES and *Blueprint for Change,* the report of the Conference on the Revolution in Earth and Space Science. The program uses *Dr. Art's Guide to Planet Earth* by Art Sussman and materials from the GLOBE program as an introduction to Earth system science. (See http://www.planetguide.net/.)

Web-Based Visualizations. ESBD introduces teachers to the use of web-based scientific visualizations to teach key concepts in Earth and space science. The Institute guides teachers in learning how to evaluate visualizations and how to use them effectively in teaching. The ESBD web site has collected exemplary web resources in the Teaching Resources section.

Web-Assisted Design. Teachers use a structured online Unit Planner to design their unit according to the UBD approach. This web-based tool allows fellow participants and program staff to view the units using any web browser, thus facilitating review, feedback, and improvement. You can inspect the Unit Planner on the ESBD web site.

Peer Feedback and Support in a Learning Community. Working with a staff mentor and sharing ideas with a partner teacher, teachers refine their unit and then implement them with their students. As they teach this unit in their classroom, they study and reflect on the implementation process, recording their observations in a reflective journal. At the Spring Conference they report on their experience and share their reflections on implementation with their peers.

Web-Enhanced Professional Development. ESBD is a "web-enhanced" professional development program. The web site (www.esbd.org) contains a list of "big ideas" in Earth science, links to resources that support the teaching and learning of these big ideas, example teaching units developed by ESBD teachers, an online Unit Planner, resources such as PowerPoint slides to help staff developers deliver the ESBD program to teachers, and a list of providers offering the ESBD program. Staff developers who register as ESBD providers are able to advertise their offering of ESBD on the web site, use ESBD's online application and registration process for teacher recruitment, and use the online reflective journal to monitor participant feedback during the program.

A Rationale for the "Earth as a System" Approach

Today's students will need to make informed decisions about the future of the Earth. As adults they will confront issues of environmental change and protection, energy supply, sustainable lifestyles, and protection from natural hazards. In order to understand these issues and make wise decisions in these areas, citizens need deep understanding of how Earth functions as an integrated system. In an age of globalization, everyone needs to understand how Planet Earth works on a physical, chemical, and biological basis. And, as Buckminster Fuller wrote, it really is "Spaceship Earth." Students will not leave school with the understanding they need unless teachers are better prepared to teach about our unique planet and its interconnected systems. The

"Earth as a system" approach not only provides the kind of integrated understanding that students need to acquire, it is increasingly the model of understanding that scientists employ in studying the Earth. Geologists, oceanographers, meteorologists, and others increasingly place their particular research in the context of an entire Earth system. If students are to have an accurate understanding of these disciplines, they need to be taught by teachers who understand planet Earth as a whole.

Teachers as Designers

We often hear that teachers should not design curriculum, that excellent curriculum already exists and that teachers need only teach it. In our experience, however, teachers are already curriculum designers. They are constantly "creating curriculum." They are deciding what parts of textbooks to use, what chapters to leave out, adding new activities, writing quizzes and tests, and designing new lessons. Teachers are searching the web for activities, borrowing from each other, and bringing back activities from conferences. It seem to us that teachers are de facto designers. The point is, however, to make them better, more informed and thoughtful designers. Teachers who have participated in ESBD tell us that, of course, they have designed lessons and units of study, but now, often for the first time, they are learning how to really construct a coherent set of lessons, aiming at the big ideas. As one teacher told us, "Why didn't I learn this in graduate school?" The fact is, of course, that in a way perhaps he had. But curriculum design had been crammed in amongst ten other topics in an education course and there had been no time to spend actually creating a unit, with feedback from mentors and peers, then to try it out, reflect on how it worked, and revise it in the light of experience.

In ESBD we aim to share with teachers the best of what curriculum designers know, to open the "black box" of good design, not so that they can redesign all their curriculum (though some do try to do this) but so that they see the "logic" of curriculum. Seeing the logic means understanding backwards design, understanding the critical role of assessment, understanding the need to uncover students' prior knowledge, and understanding the need to show students where the unit is heading and then lay out a sequence of activities that will help them to construct their own understanding.

What Teachers Say About ESBD

Teachers from novices to veterans and from those well-trained in Earth science to those with little training have found ESBD to be a valuable part of their professional growth. Here is a sample of what teachers have written about their experience:

> *"Because of this program I now know how to pull out the most important components first and use the Understanding by Design method to look at the bigger picture."*

> *"It really gave me an understanding of how to plan a unit."*

"The biggest change for me is better alignment of what I am teaching to the big ideas. The big ideas are not floating around morphing in my head anymore. They are finally defined and I am insuring that what I teach will actually help students understand the big ideas. The connections are clearer to me."

"It was very influential. I feel like I have learned a new way to think. We were given a useful framework to plan and think within that will produce clear, focused units. This really allows me to write the type of curriculum and assessment I really like. Now my students will be able to successfully complete the creative performance assessments I write."

"It is a lot of work to make a unit in this way but at the end the unit is more focused and better thought through. I feel it has been a huge help to me because it has altered my way of thinking. In the end teaching may really be less stressful when a full year is taught this way."

"It has helped me to determine what I want my students to know, and then how to get them there."

"It changed my way of teaching and designing curriculum. No longer will I just look for activities that engage students. Now I have a purpose for each activity I teach, it relates to something else. My students can see the big picture and make connections in their learning."

"I am more organized about teaching in general-feel as if I have a framework into which I can fit all my teaching- I will probably not do all this planning for each unit in each subject but will always from now on use the enduring understandings and essential questions to start a unit. I would tell them this is great program. I plan to give a workshop at my school on UBD so everyone can have a sense of this."

"Earth Science by Design has given me a renewed enthusiasm for teaching and learning."

"I will probably never teach the same way again."

For more detail on teacher experiences in ESBD, consult the SRI evaluation report on the ESBD web site (www.esbd.org).

Introduction

The Structure of the ESBD Program

ESBD is designed in accordance with the best practices of teacher professional development. It is sustained, intellectual, reflective, and grounded in practice. ESBD provides 120 hours of professional development spread over nearly a year.

Summer Institute	80 hours
Fall Conference	16 hours
Peer observation	8 hours
Spring Conference	16 hours

Teachers spend additional hours revising and teaching their unit, writing observations and reflections in their journals, and preparing their implementation report.

The two-week Summer Institute is a big commitment. But teachers have said that this two weeks to focus on UBD, on Earth science content, on visualizations, and on designing a unit they will teach is a "precious gift." Seldom, they say, do they get the concentrated time to work together with colleagues and mentors to focus on their curriculum in this kind of depth.

The Fall Conference reconvenes participants with the staff developers to review and deepen their understanding of UBD and "how people learn" and to fine tune their units before teaching them.

The peer observation involves release time to visit the classroom of another teacher in ESBD. Many teachers have told us that observing a fellow participant teaching is a unique opportunity for professional growth which they have never experienced and which they find very valuable.

The Spring Conference replicates a professional conference in which peers present the results of their work for mutual review. Each participant prepares a report and either a poster or a PowerPoint presentation sharing their implementation experience. In conferences we have observed, teachers have often shared artifacts of student work and results of student assessments. It is a culminating experience in which participants reflect on the results of their unit design and teaching and make plans to carry their work forward. In several cases, teachers have continued to meet as an ongoing professional learning community.

Is ESBD for You?

ESBD has proven to be effective in promoting teacher learning and change. It is an "out of the box ready to go program," but given the large commitment of time, staff, and money that it requires, a district or organization needs to be sure that ESBD fits their needs before deciding to offer it to their teachers. For it to be deployed successfully requires high-level support in the school district or other institution where it is being used. A team of staff developers must be assembled, teachers recruited, meeting space provided, and a budget to support the work be provided. Above all, there must be a commitment to sustained professional development for science teachers.

Introduction

In order to reach a decision whether to deploy ESBD, administrators, staff developers, science supervisors, and teachers will need to become convinced that ESBD promises sufficient results to justify the investment of time and money. To help reach a decision, read this Introduction, review the *Handbook* and consult our web site (www.esbd.org) where you will find PDF files of the evaluation reports on ESBD conducted by SRI International along with testimonials from teachers who have participated in ESBD. It may be especially useful to view the *ESBD DVD* to see and hear teachers describe their experience with the program. This will provide a good sense of the potential and the challenges of the program. Perhaps the most useful thing to do is to peruse on the web site example units that teachers in the program have produced. Contact us at TERC or AGI if you want further information about the program or when you have decided to adopt ESBD. We will help you become a registered provider and gain full access to the program tools on the ESBD web site. Call TERC: 617-547-0430 or AGI: 703-379-2480).

Special Note to College Faculty

If you are a college professor who prepares Earth science teachers, consider whether parts of the ESBD program may be useful in your work. Although ESBD has been designed as a year-long in-service experience for a cohort of teachers led by a team of staff developers, much of the material may be suitable for use with pre-service teachers as well. Please let us know if you find new pre-service uses for our materials. If you want your students to use the online Unit Planner, contact us to register yourself as a provider. Contact us if you would like to explore possible collaborations.

Implementation Guide for Staff Developers

Once you have decided to implement ESBD the first thing you need to do is to contact the ESBD project and arrange to become a *registered provider* so that you and your teachers can use all the tools on the web site. Then you should assemble your team and begin preparing yourselves to deliver the program. Here are the major milestones in the program.

The Earth Science by Design Program Year

Season	ESBD Event	Teachers' Work	Leaders' Work
Fall & Winter	Research the ESBD program for possible implementation		Review ESBD Handbook & web site to determine the nature of the program and the level of effort required to implement ESBD. Contact the ESBD project via the web site for more information if needed.
Spring	Register as an ESBD site; prepare to implement ESBD	Fill out online application at ESBD web site	Contact TERC to join ESBD program & register as a PD provider; advertise the ESBD program to recruit teachers; review teacher applications online; accept teachers to the program; notify teachers of program schedule; recruit program staff; prepare for the Summer Institute
Summer	Summer Institute (10 days; 80 hours)	Learn ESBD; develop ESBD unit to teach	Conduct the Summer Institute
Late Summer	Online & telephone mentoring	Continue to develop & refine unit; help partner refine unit	Begin online & telephone mentoring; review teacher units; help teachers improve their units
Early Fall	Fall Conference (2 days; 16 hours)	Attend Fall Conference; deepen ESBD ideas; refine ESBD unit	Conduct the Fall Conference
Fall into Winter	Implementation of the Unit	Teach the unit; keep journal; peer visit; prepare implementation report	Continue mentoring; visit classrooms
Spring	Spring Conference (2 days; 16 hours)	Present implementation report	Conduct the Spring Conference

Advance Planning

Planning for the institute and the entire ESBD program should begin early in the calendar year if not before. The dates of the summer institute and the two follow-up teacher conferences should be determined and meeting space reserved. Staff should be selected, the program advertised, and teachers recruited. Budgets should be planned and other arrangements made to cover the costs of the program. Books and materials should be ordered.

Gather An Implementation Team

As a staff developer, your task will be to lead a group of teachers through a year of ESBD professional development. To do this, you will need an implementation team of 2 or 3 professionals. The team leader should be experienced in conducting professional development programs and should have good managerial and interpersonal skills. The team leader will be the primary contact with the ESBD project at TERC.

At least one member of your team should be very well trained in Earth system science. This person could be a professional scientist or an experienced Earth science teacher, but should be able to engage productively with science teachers around the science issues. The team leader should function as an approachable "resource person" on the fundamental science questions.

One staff member should have extensive experience in teaching science and be able to engage teachers in issues of pedagogy, subject-matter content, standards, assessment, and classroom management. It is a plus if the person has district-level experience in curriculum development or professional development.

In addition, it will be very useful to have 2 or 3 experienced teachers who do not take direct responsibility for conducting the program but who serve as resources to the participants and can help with the organization of the physical materials and resources at the summer institute and the two conferences.

To get a sense of the skills and experience you will need on your team, look over the agendas and activities for the ten days of the summer institute. Think about the skills and experience needed to lead these activities.

Steep Yourselves in Understanding by Design

ESBD is based on Understanding by Design. It will, therefore, be very helpful if you and your team are as familiar as possible with the UBD approach. Get and read Understanding by Design. Read as much of it as you can, and talk with colleagues about the ideas. Perhaps form your team into a study group that reads the book together. Talk to others who have experience with UBD. Read carefully through the first week of activities in the ESBD Handbook for the summer institute. View the PowerPoint slides that accompany the activities. ESBD presents UBD in a practical and compact way that may be easier to comprehend initially than the original source.

Familiarize Yourself with the "Earth as a System" Approach

At least one member of your team should be highly qualified in Earth science. In order for the entire team to have the same vocabulary and understanding of the Earth as a system approach, we suggest that you study and discuss the book *Dr. Art's Guide to Planet Earth,* which is used as one of the books for the participants.

View the *Reports from the Field* DVD

This video not only contains interviews with ESBD teachers reflecting on their experience, it contains excerpts from one of our early spring conferences, in which staff and teachers show what an ESBD conference is like. Viewing this DVD with your team may be very valuable to orient you to ESBD and what teachers may experience.

Review Example ESBD Units on the Web Site

Nothing will give you a more concrete notion of the goals you are aiming for than looking at units that ESBD teachers have created. On the web site we have posted a number of quite good, but still fairly typical units that teachers in the program have created. You can read them online or print them out to read. Reviewing some sample units with your team is an excellent way to develop a common understanding of "where" you are headed.

Recruit Teachers

The program is designed for a cohort of 15-25 teachers. It is up to you to recruit them, but ESBD can help you advertise your program on our web site and will let you use our *online application* to register your teachers in our database, which then forms a useful resource for you and the participants in your program. When you are ready to "adopt" the ESBD program, go to the web site (www.esbd.org) to find out how to obtain a login and password and how to enter the information for your program's "advertisement."

Plan Computer Use

The ESBD web site (www.esbd.org) is a powerful tool supporting the implementation of the ESBD program. General information about ESBD, the list of Big Ideas, the Teaching Resources and example ESBD units developed by teachers are available to the public. However, each registered ESBD provider and participant has a Login and Password that allows access to additional tools and resources on the web site. Staff developers should contact ESBD through the web site to become a registered provider.

You will need an Internet-connected computer and projection system during the summer institute and the two conferences. Each teacher should have access to an Internet-connected computer with a web browser for the entire summer institute. A computer lab adjacent to the room where you meet for whole-group discussions is ideal. You will not need to install any software, but access to web browsing is essential.

On the ESBD web site you will find sets of PowerPoint slides to accompany many of the ESBD activities. You can download these and store them on your own presentation computer. They make leading the activities much easier!

The web site contains PDF files of this entire Handbook which you can download and print for your team members and PDF files of all the workshop Handouts which you can download and print for the participants.

Teachers will use the ESBD web site and web searches to locate materials for the UBD units they will develop. They will develop these units using the ESBD online unit planner accessed through the web site. You or a designated person on your team will

give each teacher a log in and password so they can access the site. You will contact the ESBD project to gain access yourself.

When teachers apply to your ESBD program using the online application, the data they provide about themselves is stored in a database which you can access to review the application. Again, you need to have your own login and password to do this. The applicant information also is used to create an online directory of all the participants in your program, which makes it easy for you all to stay in touch with each other.

Materials You Will Need to Implement the Program

These are the materials you will need to implement ESBD with your teachers. Some are provided free, some you can download, and some you will need to buy. Plan ahead and order what you need in time for the summer institute.

- *This Handbook*. You can download the entire book as PDF files from www.esbd.org and print extra copies.
- *PowerPoint slides* to accompany the workshops (download from www.esbd.org).
- A set of workshop handouts for each participant (download for printing from www.esbd.org).
- One copy of *Understanding by Design, Expanded Second Edition* by Grant Wiggins and Jay McTighe for each participant (order from ASCD at www.ascd.org. ASCD members receive a discount and even fairly small orders receive a quantity discount).
- One copy of *Dr. Art's Guide to Planet Earth* for each participant (order from http://www.planetguide.net/).
- One copy of the *GLOBE Earth system poster* (order Item 300.1-10P from http://education.nasa.gov/edprograms/core/home/index.html). You can also obtain a color jpg file of the entire poster at http://www.globe.gov/fsl/educornimages/poster_letter_color.jpg. PDF files of the poster can be downloaded from www.esbd.org.
- One copy of the *Earth Science by Design DVD: Reports from the Field* (included with this *Handbook*—order extras from www.esbd.org).
- Access to the ESBD web site—www.esbd.org.
- One copy of *A Private Universe DVD* (order by sending an email to private.universe@cfa.harvard.edu–available for free at the time of printing of this Handbook).
- Normal workshop supplies: pens, paper, markers, poster paper, etc.

Using the Guides

In the guides for the Summer Institute, Fall Conference, and Spring Conference that follow, we have included the description, goals, materials, and procedure for each activity for each day. In many cases we have included notes to the activity, in which we share with you the experience we gained from developing and testing the materials.

Remember, you can download a PDF file of the participant Handouts from the web site, which will make it easy for you to reproduce them for inclusion in an ESBD notebook for the teachers you work with.

Contact us to get started and with any questions and then, as you implement the program, let us know about your experiences. We sincerely hope you enjoy implementing Earth Science by Design with your teachers!

Adapting ESBD to Your Own Needs and Circumstances

Of course, we know that you will not implement ESBD exactly as we have planned it. We know you will look it over and then adapt it to your own needs and circumstances. However, we want to caution you not to adapt it so completely that you lose its power. Eight sets of staff developers like yourselves have field-tested it as it is written. They have been successful. The evaluator concluded that they were able to implement it much as the TERC/AGI team had done and that the results with teachers were largely the same. If you adapt it too much you may eliminate some of the very things that contribute to its success. In particular, we caution you:

- Do not shorten the summer institute; teachers need the full two weeks to digest UBD and to work together with you on their units
- Do not forgo the Fall Conference; teachers need to reconnect, deepen their understanding, and fine tune their units before teaching their units
- Do not neglect the mentoring; teachers need feedback and help from you and your staff in order to craft their units
- Do not eliminate the implementation reports; teachers need to pull together their reflections and experience in a formal report
- Do not forgo the Spring Conference; teachers need to share their implementation experiences to achieve closure on their work; the conference activities help teachers process and reflect on their experience so that it becomes useful knowledge for them

Patterns of Teacher Change

As you prepare to implement ESBD it may be helpful to read about the patterns of change we observed in the teachers in the pilot and field tests and to read about the typical challenges they faced.

Six essential questions guide the work of ESBD.

- How do we teach for *understanding* in Earth system science?
- How do we design appropriate *assessments* to evaluate understanding in Earth system science?
- How do we move students from their strongly held *misconceptions* towards more enduring understandings in Earth system science?
- How do we use scientific *visualizations* to build understanding in Earth system science?
- How do we use *reflection* to understand and improve teaching?
- What are the characteristics of an *Earth Science by Design* teacher?

As teachers move through the program, they are guided to reflect on their evolving understanding of these essential questions. Like all essential questions, they require complex, multifaceted responses, and cannot be answered in simple ways. The teachers who participated in the pilot- and field-testing of ESBD reported significant changes in their teaching. Below are examples of the patterns of change we have observed.

Teachers changed the way they plan Earth science lessons.

Three themes emerged as participants shared how ESBD affected their planning process. They described 1) focused, rather than haphazard selection of unit activities; 2) a unit aimed at deep understanding; and 3) more frequent use of visualizations. One participant described the ESBD planning process in this manner, "I have always looked for activities that are fun and engaging but I have never really looked at *exactly* where it is leading me/us. By developing a unit 'backward', I know where I want to go. I can then look at each activity closely and see if it is leading me there. I now look at all my units to see where I want to go first, then I look at the activities to see if they are going to get me there."

Teachers changed their thinking, planning, and behavior regarding assessment.

Teachers indicated that participation in ESBD significantly changed their assessment practice. Participants indicated that they 1) paid more attention to student misconceptions, 2) created more thoughtful assessments aligned to enduring understandings, 3) used a variety of assessments more frequently during a unit to check their students' understanding, 4) were much more focused on student learning as opposed to the process of teaching, 5) were more likely to ask students to share their thinking

via daily written reflections, and 6) thought about assessment at the beginning of units, rather than only at the end. One teacher wrote, "This unit is entirely different from units I have designed in the past because it had a focus from the beginning. By starting with the final assessment I had a road map to guide me through the process and an end in sight. Prior to the ESBD experience I would just pick out a bunch of learning activities and try and figure out a way to string them together to make a unit; I never even thought about the final assessment until the end." Another said, "My assessments were more thoughtful and linked to enduring understandings. I found myself really trying to understand where kids were at in their thinking and "re-teaching" on a much more regular basis."

Teachers changed their teaching strategies based on evidence of student understanding.

Using pre- and post-conception assessments helped teachers to identify, attempt to understand, and then create situations where students could confront their misconceptions. Some teachers even carried this a step further. For example, during a unit on plate tectonics, one teacher analyzed her preconception quizzes and discovered four different models that students held about the mechanism for plate tectonics. Instead of simply dismissing the incorrect models and presenting the correct model, she brought the student models to the forefront and had them analyze and discuss the adequacy of the models.

Teachers changed the way they conceptualize an Earth science unit.

Teachers revised their thinking about what constitutes a unit of instruction. One participant reflected, "A major change in my approach to teaching and learning has been that I now view a unit as one cohesive collection of ideas. A unit is not built out of facts and information that just relate to each other, but information and knowledge that must be learned and then understood collectively to have a deep understanding of the big ideas or themes that make up the unit".

Teachers changed the way they conceptualize Earth science as a discipline.

Teachers repeatedly described how the Earth as a system approach that was introduced through *Dr. Art's Guide to Planet Earth*, revisited through computer visualizations, and emphasized throughout the summer institute permeated their thinking and teaching about Earth science. One participant shared, "My picture of Earth is much more whole, interrelated, and extensive than it was. I feel I have a new sense of the strength and fragility and the significance, the miraculousness of this planet. I also have a greater sense of the connectedness of everything on Earth. I feel I conveyed these feelings much more to my students than I have in the past."

Teachers increased their content knowledge in Earth science.

Although the ESBD program provides very minimal subject matter training, participants reported that the program helped them increase their content knowledge

in Earth science. The process of creating an *Earth Science by Design* unit led them to think more deeply about the content they were planning to teach. Participants described three main factors that impacted their Earth science content knowledge: 1) using online resources and visualizations; 2) sharing ideas about their units with colleagues; and 3) the curriculum design process itself.

Challenges of Implementation

In the pilot and field testing we learned much about the challenges that teachers face as they implemented their ESBD units. View the *ESBD DVD: Reports from the Field* to see teachers express these challenges in their own words. As the teachers in the video explain, all teachers invest significant time outside the scheduled program workshops to work on their units. 76% of field-test teachers indicated that "finding time to prepare the unit" was a challenge. Year one teachers reported spending an average of 18 hours developing their units; year two teachers reported spending 37 hours. Fifty-eight field test teachers who responded to this question on a survey indicated an average of 36 hours, but with a tremendous range. Sixteen teachers spent 10 hours or less; 18 teachers spent 11-30 hours; 17 spent 40-80 hours; and 6 teachers spent over 100 hours working on their units. Most teachers indicated this was much more time than they typically devoted to designing a unit, if they actually *designed* a unit at all. Teachers said that the major challenges to designing an ESBD unit were the amount of time required and needing to deepen their own content knowledge in order to prepare the unit.

Teachers reported that their ESBD unit took longer to teach than a similar one had taken them in previous years. As a result, they tended to feel guilty about the length of time they took. They expressed worries about standardized testing. They were frustrated when they hit technology barriers such as not being able to get computer lab time, encountering Internet sites with inconsistent performance, and hitting firewalls on school computers that made access to certain visualizations impossible. Teachers found the process of designing performance assessments and rubrics to be both difficult and time consuming. Many teachers had designed performance assessments in the past but seldom took so much care to align them with enduring understandings and learning activities.

Teachers also became keenly aware of school-level factors that made incorporating an ESBD approach difficult. They talked about how the culture of the school affected them and about the constraints imposed by an overloaded curriculum. One participant shared this insight, "I think that doing this unit has pushed me to see that the setting I am in does not allow me to collaborate and teach to the depth that I would like." Another reflected, "The key question raised for me is how can I teach for understanding and teach the vast array of topics my students are expected to be fluent in for the state eighth grade science test? There is so much I need to teach that I find fighting the notion of *coverage* to be a daily battle. As a result of my wonderfully

engaging ESBD unit where students were begging for more days to develop their geo-resorts, I am going to have to race through the rock cycle. It is a shame not to give every area of content the depth that my ESBD unit has had."

The ESBD program is demanding. Most teachers indicated that implementing their ESBD unit took significantly more time than ways they had covered the same material in the past. However, 80% said that the educational effectiveness of the ESBD unit offset the greater amount of time that the unit took and 93% indicated that they will use their unit the next time they teach the same content. Teachers also expressed a strong desire to revise all of their units into an ESBD format. Recognizing the time constraints they face, some teachers have begun to adapt and teach each other's units. Teachers reported that they benefited tremendously from the interactions and discussions about teaching and learning that they had with their mentors and peers throughout the program.

For more detail on teacher and staff developer experiences in ESBD, consult the evaluation report on the ESBD web site (www.esbd.org).

Earth Science by Design

In the Understanding by Design Framework

Stage 1: Identify Desired Results

Revolutionize the teaching and learning of Earth science.

Move Earth science teaching:

- from a pedagogical focus on facts and coverage toward a focus on big ideas, "uncoverage," and deep understanding;
- from instructional units made up of short-term activities toward units organized according to UBD principles;
- from assessment that uses paper and pencil quizzes and end-of-unit tests toward a suite of assessments that monitor and motivate student understanding;
- from curriculum that is "a mile wide and an inch deep" toward fewer topics taught more deeply and in the framework of "Earth system science";
- from using visual aids drawn largely from a textbook toward creative use of web-based scientific visualizations.

Program Description

ESBD is a year-long professional development experience which helps participants apply "teaching for understanding" (as described in *Understanding by Design*) to the teaching of Earth system science. During the summer institute, teachers develop an Earth science unit following the UBD approach, in which they incorporate scientific visualizations and other technologies used in contemporary Earth science research. They critically examine these and other resources to determine how they can be used to teach the "Big Ideas" in Earth system science. Participants learn to design assessments that evaluate understanding. Teachers reflect upon their teaching as they implement their unit. They observe and offer feedback to a peer during the implementation of an *Earth Science by Design* unit.

Overarching Enduring Understandings

- Understanding is complex, multifaceted, and often elusive.
- Well-designed assessments provide evidence of understanding and guide teaching.
- Learners have strongly held misconceptions in Earth system science that often go unnoticed.
- Carefully selected visualizations presented in the context of well-planned sequences of learning activities can build understanding in Earth system science.
- Reflecting on teaching practice informs teaching and can improve it.

- The effective creation and implementation of an *Earth Science by Design* unit takes time and may be challenging, but ultimately helps ensure that the conditions necessary for building deep and enduring understanding will occur within the learning environment.

Essential Questions

- How do we teach for *understanding* in Earth system science?
- How do we design appropriate *assessments* to evaluate understanding in Earth system science?
- How do we move students from their strongly held *misconceptions* towards more enduring understandings in Earth system science?
- How do we use scientific *visualizations* to build understanding in Earth system science?
- How do we use *reflection* to understand and improve teaching?
- What are the characteristics of an *Earth Science by Design* teacher?

What participants will need to know and be able to do (knowledge and skills)

- Demonstrate a clear and practical idea of "understanding" and its place in education.
- Understand the role of the six facets of understanding in teaching and learning.
- Analyze, organize, and prioritize instructional goals in terms of the UBD framework.
- Recognize and develop essential questions for a unit of study in Earth science.
- Understand the conceptual framework of Earth system science.
- Understand the crucial role of assessment in the Earth Science by Design approach.
- Select, adapt, or design appropriate assessments, including authentic performance assessments, to evaluate students' understanding.
- Be alert to the importance of misconceptions and prior knowledge.
- Use effective strategies to reveal and address student misconceptions.
- Design learning experiences using the WHERETO approach.
- Understand the value and role of scientific visualizations in Earth science and incorporate them in learning designs to help students understand Earth system science.

- Analyze, evaluate, and provide feedback on the learning designs of peers.
- Understand the value of reflection to improve teaching practice.

What might participants misunderstand about Earth Science by Design?

- Only "the big ideas" are important to teach.
- The ESBD approach takes too much time.
- The ESBD approach has no place for "traditional tests and quizzes".
- Factual knowledge is unimportant.
- Learner misconceptions can be easily erased, especially through direct instruction.
- Any kind of Internet use enhances learning and technology skills.
- "Uncoverage" means kids must discover everything themselves.
- If you give students correct information, they will learn it.
- Good performances on quizzes and tests indicate enduring understanding.
- All visualizations are effective.
- Direct instruction has no place in Understanding by Design.
- Learners must acquire skills and knowledge before they can begin to uncover the essential questions in a discipline.
- ESBD requires teachers to create entirely new activities and curriculum.
- *Understanding by Design* is a radical new approach.

Stage 2: Determine Acceptable Evidence

Performance Tasks

- *Create An Earth Science by Design Unit.* During the two-week summer institute, participants will create an Earth Science by Design unit to teach during the coming school year.
- *Evaluate an Earth Science by Design Unit.* During the summer institute, participants will serve as peer evaluators of each other's work to offer feedback on the strengths and weaknesses relative to the Understanding by Design criteria.
- *Attend the Fall Teacher Conference.* At this conference, participants will present a revised version of their unit. This is an opportunity to receive feedback and suggestions from peers and mentors before beginning to implement the unit.

- *Implement an Earth Science by Design Unit.* Participants will implement an Earth Science by Design unit in their classrooms following the Fall Teacher Conference.
- *Evaluate an Earth Science by Design Lesson as It Is Taught.* Each participant will serve as a peer evaluator for another participant as they implement the Earth Science by Design approach in their classrooms.
- *Prepare an Implementation Report for the Winter Teacher Conference*. Each participant will prepare a report on the implementation of their unit, which they will present and share at the conference. The report should be a written document, following the guidelines provided, but may include a PowerPoint presentation or a poster as well.

Academic Prompts

- *Daily Reflection During the Summer Institute.* Participants will write responses to reflective questions such as, "What is the main understanding that you struggled with today?" and "What is the main unanswered question you leave the institute with today?"
- *The Earth Science by Design Journal*. Participants will reflect upon their teaching practices and student learning as they implement their Earth Science by Design unit. These reflections and notes form the basis for the implementation report.

Stage 3: Plan Learning Experiences and Instruction

See the detailed guides for the Summer Institute, Fall Conference, and Spring Conference, which follow.