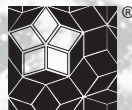


Earth Science by Design Handbook for Professional Developers

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



TERC



TERC, Cambridge, MA

Developed with funding from the National Science Foundation
Copyright© 2006, TERC and the American Geological Institute

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

Copyright TERC and the American Geological Institute, © 2006. All rights reserved.



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 Klawns, 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 <i>Earth Science by Design</i>	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
<i>Earth Science by Design</i> in the <i>Understanding by Design</i> 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

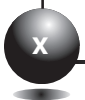


Table of Contents

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 EBSD Unit (edited)	12
HANDOUT 4	Earthquakes and Volcanoes: An EBSD Unit (edited)	14
HANDOUT 5	Global Warming: What is It and What Can	
	We do About It? An EBSD Unit (edited)	15
HANDOUT 6	Daily Weather: An EBSD Unit (edited)	16
HANDOUT 7	Reviewing The Six Facets of Understanding - Definitions	
	from Understanding by Design	19
HANDOUT 8	Perspective and EBSD	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 Session44
	HANDOUT 20	Earth Science by Design Classroom Observation Guide: Completed Sample47
	HANDOUT 21	Implementation Report Guide53
	HANDOUT 22	Spring Conference Presentation Guide55
Spring Conference Handouts	HANDOUT 1	Discussion Questions for Building Enduring Understanding in Your Classroom8
	HANDOUT 2	Guiding Questions for Presentations on Student Understanding ..10
	HANDOUT 3	Discussion Questions for Assessing Student Learning in ESBD12
	HANDOUT 4	Discussion Questions for From Misconceptions to Enduring Understanding18
	HANDOUT 5	Presentation Guidelines for Panelists.....20
	HANDOUT 6	Discussion Question for How ESBD has Affected Me as a Teacher and a Learner22

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.earthscienceeducationrevolution.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

Introduction

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. ESDB 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. ESDB 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 ESDB 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 ESDB 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. ESDB 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 ESDB teachers, an online Unit Planner, resources such as PowerPoint slides to help staff developers deliver the ESDB program to teachers, and a list of providers offering the ESDB program. Staff developers who register as ESDB providers are able to advertise their offering of ESDB on the web site, use ESDB’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

Introduction

“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 seems 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 ESDB 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 ESDB 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 ESDB

Teachers from novices to veterans and from those well-trained in Earth science to those with little training have found ESDB 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.”

Introduction

“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.

Introduction

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

Introduction

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 Yourself 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.

Introduction

View the Reports from the Field DVD

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

Review Example ESDB 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 ESDB 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 ESDB 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 ESDB 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 ESDB web site (www.esbd.org) is a powerful tool supporting the implementation of the ESDB program. General information about ESDB, the list of Big Ideas, the Teaching Resources and example ESDB units developed by teachers are available to the public. However, each registered ESDB provider and participant has a Login and Password that allows access to additional tools and resources on the web site. Staff developers should contact ESDB 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 ESDB web site you will find sets of PowerPoint slides to accompany many of the ESDB 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 ESDB web site and web searches to locate materials for the UBD units they will develop. They will develop these units using the ESDB online unit planner accessed through the web site. You or a designated person on your team will

Introduction

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.

Introduction

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 ESDB 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 ESDB to Your Own Needs and Circumstances

Of course, we know that you will not implement ESDB 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

Introduction

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

Introduction

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

Introduction

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 ESD 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 ESD 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 ESD 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 ESD 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

Introduction

engaging ESBD unit where students were begging for more days to develop their georesorts, 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).

Introduction

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, “un-coverage,” 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.

Introduction

- 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.

Introduction

- 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.

Introduction

Academic Prompts

- *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.
- *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.

Summer Institute

SUMMER

Table of Contents

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 WHERETO 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 WHERETO to the Rock Cycle Unit – Part One	124
Activity 17. Applying WHERETO to the Rock Cycle Unit – Part Two	127
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

Summer Institute

SUMMER

Table of Contents

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

Summer Institute

DAY 1

SUMMER INSTITUTE

Day 1 Overview

The morning activities introduce the concept of deep and enduring understanding, introduce the six facets of understanding, and give an overview of the ESBD program. The afternoon activities introduce the Big Ideas and the Earth system science approach.

Day 1 Schedule

8:30-8:45	Welcome and overview of the week
8:45-9:05	Igneous Fusion
9:05-10:00	Understand Me
10:00-10:15	Break
10:15-11:15	Looking at Understanding
11:15-11:45	What is Earth Science by Design?
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	What is Worthy of Understanding?
2:00-2:15	Break
2:15-3:15	An Introduction to Earth System Science
3:15-3:30	Reflection

Summer Institute

DAY 2

SUMMER INSTITUTE

Day 2 Overview

The morning activities focus on Stage 1 of the UBD/ESBD model. Working in small teams, the participants begin to design Stage 1 of a sample unit. The afternoon activities focus on Stage 2, with participants creating an authentic performance assessment and a rubric to evaluate it.

Day 2 Schedule

8:30-8:45	Welcome and overview of the day
8:45-9:30	Designing an ESBD Unit: Enduring Understandings
9:30-10:15	Designing an ESBD Unit: Essential Questions
10:15-10:30	Break
10:30-11:30	Designing an ESBD Unit: Knowledge, Skills, and Typical Misunderstandings
11:30-11:45	Reflection
11:45-12:45	Lunch
12:45-1:15	Introducing Assessment
1:15-2:00	Designing Performance Assessments
2:00-2:15	Break
2:15-3:15	Creating Rubrics
3:15-3:30	Reflection

Summer Institute

DAY 3

SUMMER INSTITUTE

Day 3 Overview

Today's activities focus on Stage 3 of the UBD/ESBD model. The first activity introduces WHERETO as a model for designing Stage 3 of an ESBD unit. The second activity emphasizes the importance of understanding student preconceptions before beginning to teach. The third and fourth activities introduce the use of visualizations in teaching.

Day 3 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Using WHERETO to Promote Understanding in Earth Science
10:00-10:15	Break
10:15-11:45	Investigating Preconceptions and Misconceptions in Earth Science
11:45-12:00	Reflection
12:00-1:00	Lunch
1:00-2:00	Visualizations and Earth Science
2:00-2:15	Break
2:15-3:15	Visualizations and Earth Science (continued)
3:15-3:30	Reflection

Summer Institute

DAY 4

SUMMER INSTITUTE

Day 4 Overview

Today and tomorrow are devoted to developing Stage 3 of each group's rock cycle sample unit. Participants use the WHERETO model to design Stage 3 activities for their rock cycle unit. In Part One they work in small groups, using the Internet and other resources to identify activities aligned with their Stage 1 and Stage 2 that will lead their students to deep and enduring understanding of the rock cycle. In Part Two they review the Stage 3 resources found by other groups and use them to improve their own units.

Day 4 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Applying WHERETO to the Rock Cycle Unit—Part One
10:0-10:15	Break
10:15-11:45	Applying WHERETO to the Rock Cycle Unit—Part One (continued)
11:45-12:00	Reflection
12:00-1:00	Lunch
1:00-2:00	Applying WHERETO to the Rock Cycle Unit—Part Two
2:00-2:15	Break
2:15-3:15	Applying WHERETO to the Rock Cycle Unit—Part Two (continued)
3:15-3:30	Reflection
Homework	Think about the ESBD unit you may want to develop during week two.

Summer Institute

DAY 5

SUMMER INSTITUTE

Day 5 Overview

Today concludes the teachers' work on the rock cycle sample unit. Participants are introduced to the ESBD Unit Construction Checklist and use it to check their sample unit. Today you may opt to review any aspects of the material covered earlier in the week. Some teachers especially may need a review of the work of Stage 2—performance assessments and rubrics. Teachers select two other teachers they think they would work with well as a partner. By Monday of next week leaders will create the pairings they think will be most productive. Leaders should also be gathering information about which staff members may work well with which teachers in order to assign a staff mentor to each teacher.

Day 5 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Continue work on the rock cycle unit in small groups
10:0-10:15	Break
10:15-11:00	Continue work on the rock cycle unit in small groups
11:00-11:45	Using the <i>Unit Construction Checklist</i>
11:45-12:00	Reflection
12:00-1:00	Lunch
1:00-2:00	Whole group review and celebration of all the rock cycle units
2:00-2:15	Break
2:15-3:15	Sharing ideas for units
3:15-3:30	Reflection
Homework	Over the weekend, think about the ESBD unit you may want to develop during week two. Next week, bring any materials and resources you want to have on hand as you begin to design your own unit.

Summer Institute

DAY 6

SUMMER INSTITUTE

Day 6 Overview

This week is devoted primarily to teachers working on the design of the Earth science units they will teach. The morning activities introduce and analyze a sample unit: Journey to Planet Earth. In this activity, teachers gain familiarity with satellites, the instruments they carry and the kinds of data they collect. They explore satellite data and consider its application to the teaching of Earth science. Staff leaders assign partners and teachers begin work on their units.

In the afternoon, partners begin work on Stage 1 of their units. Mentors circulate and meet with partner groups.

Day 6 Schedule

8:30-8:45	Welcome and overview of the week
8:45-9:00	Review of a sample unit: Journey to Planet Earth
9:00-10:00	Satellite Search
10:00-10:15	Break
10:15-11:15	Satellite Search (continued)
11:15-11:45	Assignment of partners and initial work on units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners work on Stage 1 of their units
2:00-2:15	Break
2:15-3:15	Continue work on Stage 1 of units
3:15-3:30	Reflection

Summer Institute

DAY 7

SUMMER INSTITUTE

Day 7 Overview

This day is devoted primarily to teachers working on the design of Stage 1 of their Earth science units. Mid-morning features a video interview of experienced ESBD teachers sharing the challenges of ESBD design and teaching, followed by group discussion of the video. The day concludes with a review of Stage 1 of the units using the Unit Checklist. Throughout the day, staff mentors circulate and assist teachers with their unit design.

Day 7 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners continue work on Stage 1 of units
10:00-10:15	Break
10:15-11:00	Report from the field: video of ESBD teachers followed by discussion
11:00-11:45	Partners continue work on Stage 1 of units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners continue work on Stage 1 of units
2:00-2:15	Break
2:15-3:15	Check units for completeness of Stage 1
3:15-3:30	Reflection

Summer Institute

DAY 8

SUMMER INSTITUTE

Day 8 Overview

This day is devoted to teachers working on the design of Stage 2 of their Earth science units. Mid-morning features a video interview of experienced ESDB teachers sharing the challenges of Stage 2 ESDB design and teaching, followed by group discussion of the video. The day concludes with a review of Stage 2 of the units using the Unit Checklist. Throughout the day, staff mentors circulate and assist teachers with their unit design.

Day 8 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners begin work on Stage 2 of units
10:00-10:15	Break
10:15-11:00	Challenges of Stage 2: video of ESDB teachers followed by discussion
11:00-11:45	Partners continue work on Stage 2 of units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners continue work on Stage 2 of units
2:00-2:15	Break
2:15-3:15	Check units for completeness of Stage 2
3:15-3:30	Reflection

DAY 9

SUMMER INSTITUTE

Day 9 Overview

This day is devoted to teachers working on the design of Stage 3 of their Earth science units. Mid-morning features a video interview of experienced ESD teachers sharing the challenges of Stage 3 ESD design and teaching, followed by group discussion of the video. Throughout the day, staff mentors circulate and assist teachers with their unit design.

Day 9 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners begin work on Stage 3 of units
10:00-10:15	Break
10:15-11:00	Challenges of Stage 3: video of ESD teachers followed by discussion
11:00-11:45	Partners continue work on Stage 3 of units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners continue work on Stage 3 of units
2:00-2:15	Break
2:15-3:15	Partners continue work on Stage 3 of units
3:15-3:30	Reflection

Summer Institute

DAY 10

SUMMER INSTITUTE

Day 10 Overview

On the final day of the institute teachers complete the first draft of the Earth science units they will teach. First drafts are printed and distributed to all participants. Each teacher is assigned a specific staff mentor for the duration of the program and meets with the mentor to review the unit and establish their relationship. Teachers receive certificates of completion, review schedule for the rest of the year, complete the on-line reflection and celebrate the completion of the Institute.

Day 10 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners continue work on Stage 3 of units
10:00-10:15	Break
10:15-11:45	Partners continue work on units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Teachers meet with their mentors Continue unit work Complete online reflection
2:00-2:15	Break
2:15-3:30	Institute Conclusion <ul style="list-style-type: none">• Print and distribute first drafts of all units to everyone• Present certificates of completion• Review schedule for the rest of the year• Celebrate completion of Institute

DAY 1

Introduction

Day 1 Overview

The morning activities introduce the concept of deep and enduring understanding, introduce the six facets of understanding, and give an overview of the ESBD program. The afternoon activities introduce the Big Ideas and the Earth system science approach.

Day 1 Schedule

8:30-8:45	Welcome and overview of the week
8:45-9:05	Igneous Fusion
9:05-10:00	Understand Me
10:00-10:15	Break
10:15-11:15	Looking at Understanding
11:15-11:45	What is Earth Science by Design?
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	What is Worthy of Understanding?
2:00-2:15	Break
2:15-3:15	An Introduction to Earth System Science
3:15-3:30	Reflection

ACTIVITY 1

Igneous Fusion: Introducing Essential Questions

Description

This introductory activity explores participants' preconceptions about student understanding and the teaching of Earth science. It introduces the essential questions of the Earth Science by Design program and provides formative evaluation data for looking at participants' reflections upon understanding and Earth science before and after the institute.

We recommend that institute staff act out a skit based on the Igneous Fusion excerpt from Handout 1. Alternatively, participants could simply read the excerpt.

Goals

Completing this activity will help teachers to:

- Recognize that teaching for understanding is complex and difficult to obtain.
- Reflect upon the nature of *understanding* and what it means for the teaching of Earth science
- Recognize the essential questions of the *Earth Science by Design* program

Materials

- ☐ Igneous Fusion PowerPoint Presentation
- ☐ *Igneous Fusion* Handout 1
- ☐ *Igneous Fusion Reflection* Handout 2
- ☐ *Earth Science by Design Essential Questions* Handout 3
- ☐ *The Layers of the Earth* Handout 4

Approximate Time

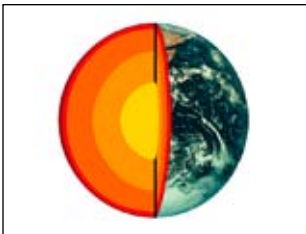
20 minutes

Procedure

1. Act out a skit based on the Igneous Fusion story.

Several staff should sit in rows at the front of the room as students in a classroom while one staff member plays the teacher and another plays John Dewey. The teacher announces to the class that they are going to have a famous visitor today—Professor John Dewey. After welcoming Dr. Dewey the teacher asks him if he would like to address the class. He answers 'yes' and puts to them the following question: "What would you find if you dug a hole in the Earth?" The class is silent and looks puzzled. He repeats the question. After an interval, the teacher says, "Dr. Dewey, you're asking the wrong question." Turning to the class, she says, "Class, what is the state of the center of the Earth?" Looking happy, the class replies in unison, "Igneous fusion!"

ACTIVITY 1 Igneous Fusion: Introducing Essential Questions - Page 2



2. Launch the Igneous Fusion PowerPoint presentation and display ppt slide 1, and then immediately, ppt slide 2.

3. Refer to Handouts 1 and 2, ask teachers to reflect on the skit, and then have them write their response to the questions from Handout 2.

Allow teachers about 5 to 10 minutes for writing. Do not discuss the scenario until after they are finished writing. (Teachers' responses to the questions reflect their preconceptions about understanding and will be revisited at the end of the Summer Institute.)

4. Display ppt slide 3 showing the internal structure of the Earth as layers represented by different colors.

Say something like: "Perhaps this typical image of a cutaway Earth immediately came to mind as you reflected upon the John Dewey story. How many students today might think that if they dug a hole in the Earth, they would find orange, yellow, and red material? Or, would they remain silent until we asked the *right* question: What are the layers of the Earth?"

5. Display ppt slide 4 and pose a question about the depth of student understanding.

Say something like:

"Do our students *really* have a *deep* and *enduring* understanding of the dynamic nature of the interior structure of the Earth and its implications for planet Earth?"

6. Display ppt slide 5 containing the essential questions for the Earth Science by Design Program.

Read them one by one as they appear on the screen.

Do not discuss them now. Just read each in turn and say that these are the six essential questions they will be investigating during this institute and throughout the *Earth Science by Design* program:

- 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?

Day 1

ACTIVITY 1 Igneous Fusion: Introducing Essential Questions - Page 3

7. Collect teachers' written reflections.

Photocopy them overnight and return the originals to the teachers at the beginning of the next day.

Notes

At the end of the day, read the Teachers' Igneous Fusion reflections and have a staff discussion about teachers' preliminary ideas about understanding.

HANDOUT 1

Igneous Fusion

Almost everyone has had the experience of being unable to answer a question involving recall when the question is stated in one form, and then having little difficulty...when the question is stated in another form. This is well illustrated by John Dewey's story in which he asked a class, "What would you find if you dug a hole in the Earth?" Getting no response, he repeated the question; again he obtained nothing but silence. The teacher chided Dr. Dewey, "You're asking the wrong question." Turning to the class, she asked, "What is the state of the center of the Earth?" The class replied in unison, "igneous fusion."

Understanding by Design (2005) p. 47-48

Original Source: Bloom (1956) *A Taxonomy of Educational Objectives: Classification of Educational Goals*, p. 29

HANDOUT 2

Igneous Fusion Reflection

Name: _____ Date: _____

What does this scenario reveal to you about the nature of student understanding and the teaching of Earth science?

What do you think understanding really is?

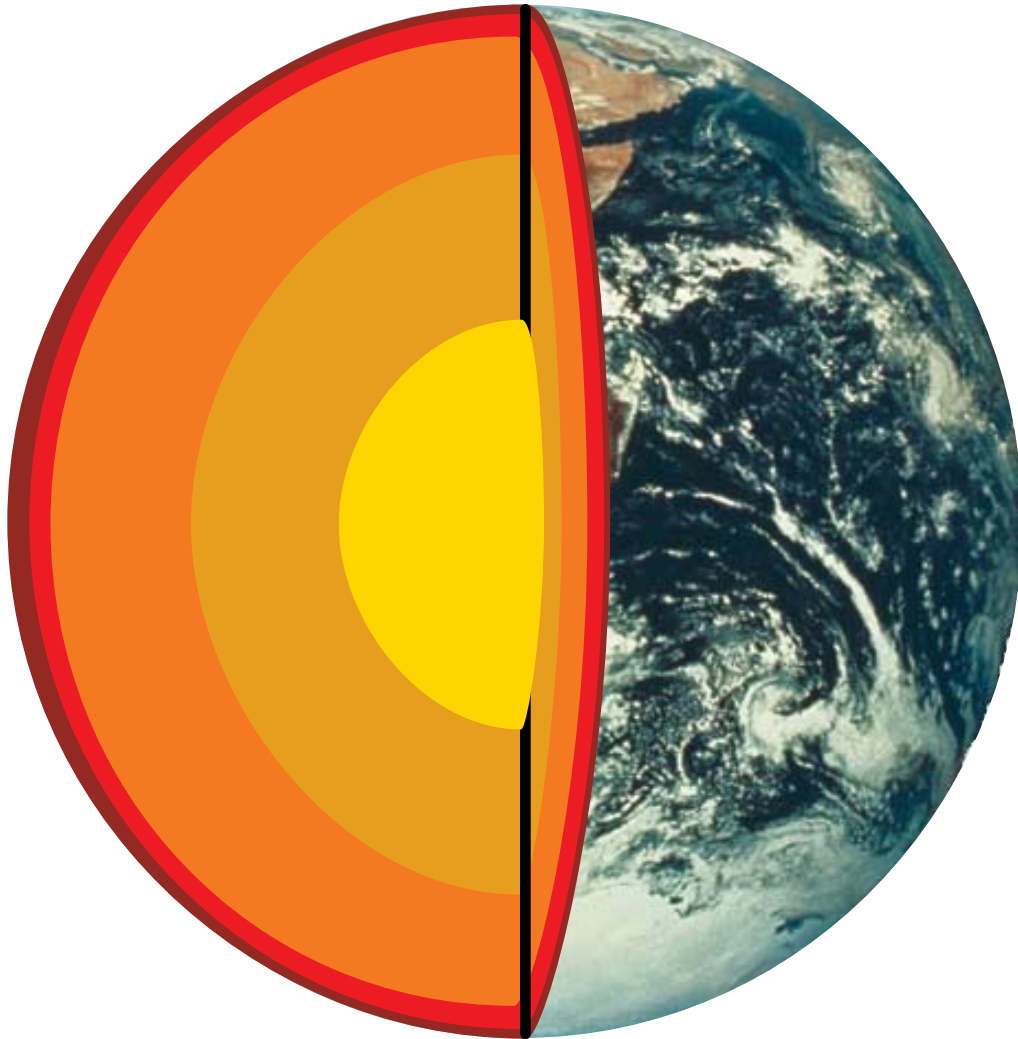
HANDOUT 3

Earth Science by Design 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* toward 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?

HANDOUT 4

The Layers of the Earth



Do our students *really* have a *deep* and *enduring* understanding of the dynamic nature of the interior structure of the Earth and its implications for planet Earth?

ACTIVITY 2

Understand Me

Description

This activity functions as both an icebreaker and an opportunity to begin thinking about what is necessary to achieve deep and enduring understanding. In this activity, participants are given a limited time to interview and then introduce each other. In the discussion that follows, teachers reflect on what builds understanding and what limits understanding. Through discussion of the process, they discover that understanding takes *time* and is promoted through asking *questions*. Next, they make a graph of understanding over time. Finally, they connect the activity experience to how understanding is pursued in the science classroom.

Goals

Completing this activity will help teachers to:

- Realize that understanding has many levels, from superficial to deep.
- Recognize that there are different aspects to understanding.
- Discover that questions and time are essential to understanding.
- Realize that understanding must be uncovered.

Materials

- ☐ Blackboard, whiteboard, or poster paper on easel.
- ☐ A *Graph of Understanding Over Time* Handout 5

Approximate Time

55 minutes

Procedure

1. Organize and explain the interview task.

Ask participants to get into pairs with someone they do not already know. Tell them that they will each have two minutes to interview each other. (Four minutes total.) After they interview each other they will each be given a minute to report to the group on what they know about their partner.

2. Ask participants to share what they have learned

Select eight volunteers and give them one minute each to share what they have learned about their partner. Be sure to stick to the one minute time limit.

3. Relate the interview task to the challenge of understanding.

After these eight volunteers have shared their interviews, ask the group: “How well do you think you know the person you interviewed? At what level do you understand this person? What kinds of things do you understand and not understand about this person? How could you understand the person you interviewed better? Were there certain kinds of questions that really helped you understand the person better?”

ACTIVITY 2 Understand Me - Page 2

4. Accept responses and try to come to a consensus.

The group most likely will agree that they do not have deep understanding of the person they interviewed because there was not enough time to really get to know the other person, that they understand the person at a somewhat superficial level (name, job, family, hobbies) and that if they do understand them more deeply it was because of something that just happened to come up. Understanding must be uncovered. Deeper understanding requires more time, more diverse situations, and perhaps different kinds of questions, such as ones that target understanding as opposed to eliciting simple factual knowledge. (10 minutes)

5. Make and discuss a graph of understanding over time.

On the board or on poster paper draw two identical copies of the graph template *A Graph of Understanding Over Time* shown at the end of this activity. Ask for two volunteers to come up to the board. Ask each to draw a graph of their idea of how understanding of a person might vary over time. Discuss the two graphs.

- How are they similar and how are they different?
- What are the shapes of the graphs? Do they each show the same kind of relationship between understanding and time? Discuss their slopes, plateaus, inflection points. Does understanding increase in a simple linear way or does it have a more complex shape?
- Does the graph have units on the time axis? What are they? How does understanding grow over time?
- Does understanding ever decrease? (Are there situations where we think we understand a person *less* well over time?)

6. Continue with the interviewing reports until everyone has been introduced.

7. Conduct a whole-group discussion on the nature of understanding.

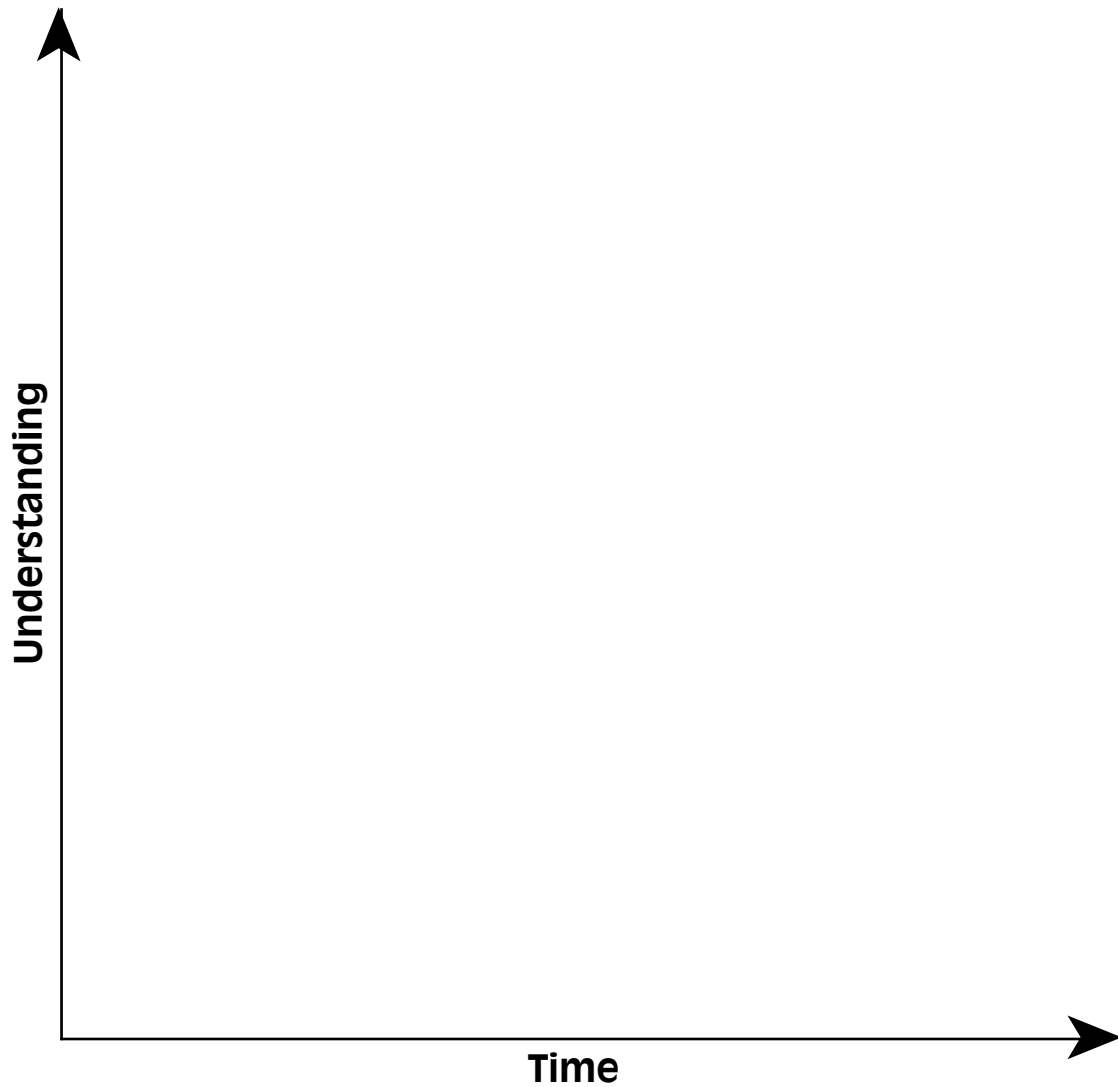
- “What have we learned about understanding?” (In-depth understanding takes time; the kind of understanding you attain depends in part on the questions you ask and on what you talk about; time alone is not sufficient for understanding.)
- “How does this relate to the classroom situation?” (The questions you ask and how you use class time make a difference in terms of the depth of understanding you get from students. The process of seeking understanding over time is dynamic. Science is not a stationary target.)

8. Conclude the activity.

Say something like “During the ESBD program, we will ask you to become students of understanding. Together we will explore *how* we understand, how we *know* we understand, how understanding *endures*, what is *worthy* of understanding, and how we *teach* for understanding.”

HANDOUT 5

A Graph of Understanding Over Time



ACTIVITY 3

Looking At Understanding

Description

This activity introduces the six facets of understanding, as described in *Understanding by Design*, and provides participants with practice applying the facets to the understanding of Earth science content. A sample narration accompanying the PowerPoint presentation has been included with this activity. Use it as needed to help guide the presentation and discussion of the facets of understanding.

Goals

Completing this activity will help teachers to

- Recognize that understanding is complex and multi-faceted.
- Apply the six facets of understanding to Earth science content.

Materials

- ☐ *Looking at Understanding* PowerPoint presentation
- ☐ One Understanding Cube per participant (assemble ahead of time)
- ☐ *Reviewing the Six Facets of Understanding Definitions from Understanding by Design: Handout 7*
- ☐ One large demonstration size Understanding Cube for the facilitator (not included—make yourself)
- ☐ *The Six Facets of Understanding: Mt. St. Helens Eruption Example Handout 8*
- ☐ *Applying the Six Facets of Understanding Handout 9*
- ☐ *Looking at Understanding Sample Narration to Accompany the PowerPoint Presentation*

Approximate Time

60 minutes

Procedure



1. Review the outcomes from the previous activity and present the goal of the current one.

Emphasize that this activity focuses on how the questions we ask can reveal different *facets* of understanding.

(ppt slide 1, ppt slide 2)

Review the Sample Narration included at the end of this activity and use as much of it as you find useful to guide your use of the PowerPoint presentation. Refer participants to Handouts 7, 8, and 9 as needed.

2. Introduce the idea that there are different ways of understanding.

Describe how explanation and application are two of these ways. Provide an example of each tied to the Mt. St. Helens images.

(ppt slide 3)

ACTIVITY 3 Looking At Understanding - Page 2

3. **Distribute the Understanding Cubes to participants.**
4. **Introduce the six facets of understanding, while pointing to each of the six facets of the large, demonstration size Understanding Cube.**
The facets are: explanation, interpretation, application, perspective, empathy, and self-knowledge.
(ppt slide 4)
5. **Clarify the difference between understanding and knowing.**
For Wiggins and McTighe, understanding means moving away from decontextualized, fragmented, learning and toward more purposeful, deep, and meaningful learning. They differentiate knowledge from understanding and advocate focusing on the higher order skills of Bloom's taxonomy.
(ppt slide 5)
6. **Explain each facet and describe an example for the Mt. St. Helens images.**
Refer to the extensive example narration found in the Notes section of the PowerPoint.
(ppt slides 6-20)
Distribute *The Six Facets of Understanding: Mt. St. Helens Eruption Example Handout* so that participants may follow along.
7. **Organize participants in groups of three or four.**
Refer to Handout 9 and assign one of the following areas to each group: cloud formation, erosion, ocean currents, planetary motion, or human population growth. Ask each group to apply the facets of understanding to their area.
(ppt slide 21)
8. **Share and discuss. Group reports back.**
Ask for one person from each group to report back to the larger group.
9. **Collect one copy of Handout 9 from each group, photocopy, and return a complete set to the participants.**

Notes

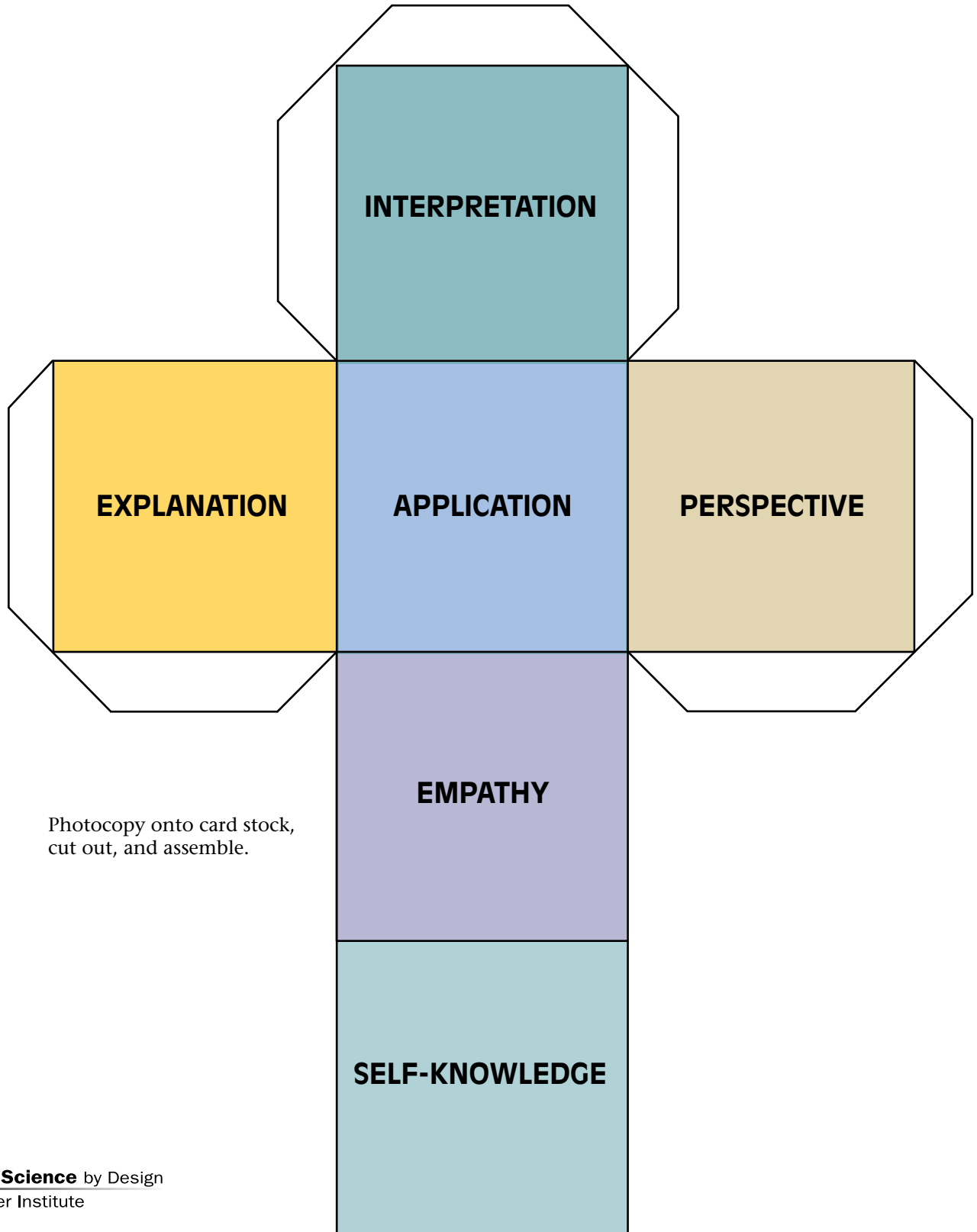
Many science teachers regularly apply and are familiar with the facets of explanation and application. The facet of self-knowledge may not be one that they frequently incorporate into their teaching. However, most do have an awareness of it. Helping to build student understanding through the use of visualizations and satellite imagery is a major way that the ESBD program addresses the facet of perspective.

Some teachers have struggled with the facet of interpretation. They often associate the facet of interpretation with “interpreting data”. When discussing what it means to “interpret” data, some describe a correlation between two lines on a graph as interpretation. However, for Wiggins and McTighe, interpretation goes beyond describing patterns in data. It is about sense making. What does this pattern in the data mean? Is the relationship spurious or does it point to other factors? In Earth science, using evidence from fossils and reconstructing past events like flooding to tell the geologic story of an area is an example of interpretation.

The facet of understanding that science teachers find the most difficult to consider applying to their teaching is empathy. However, the history of science provides many opportunities for students to empathize with early ideas from scientists. For example, rather than dismissing Wegener’s theory of continental drift as naive, students can empathize with his ideas if they understand the historical context in which he was working.

HANDOUT 6

Understanding Cube



HANDOUT 7

Reviewing The Six Facets of Understanding

Definitions from Understanding by Design

Explanation

Sophisticated and apt understandings and theories, which provide knowledgeable and justified accounts of events, actions, and ideas.

Interpretation

Narratives and translations that provide meaning.

Application

The ability to use knowledge effectively in new situations and diverse contexts.

Perspective

Critical and insightful points of view.

Empathy

The ability to identify with another person's feelings or worldviews.

Self-Knowledge

The wisdom to know one's ignorance and how one's patterns of thought and action inform as well as prejudice understanding.

HANDOUT 8

The Six Facets of Understanding

Mt. St. Helens Eruption Example:

Explanation

Explain why Mt. St. Helens erupted. Extend this explanation to include other volcanoes in the Cascades.

Interpretation

What is the geologic story of Mt. St. Helens? How has the volcano changed over time?

Application

Apply your understanding of the Mt. St. Helens eruption to make predictions of other places in the world where similar eruptions might occur.

Perspective

Examine the role volcanoes play in Earth Systems.

Empathy

Why do people choose to live near volcanoes?

Self-Knowledge

How well do you understand volcanic eruption?

HANDOUT 9

Applying the Six Facets of Understanding

Explanation

Interpretation

Application

Perspective

Empathy

Self-Knowledge

Looking at Understanding Sample Narration to Accompany the PowerPoint Presentation

ppt slide 1:



Looking at Understanding

In the last activity we discovered that understanding a subject requires “uncoverage” as opposed to “coverage” of the subject. Questions help us to get at deep and enduring understanding. But, it takes time. Now, we will consider how the questions we ask can reveal different *facets* of understanding. Today we will be *Looking at Understanding*.

ppt slide 2:



Student Understanding

Let's return to the classroom setting. Consider this typical middle school student. What does it mean for this student to *really understand* Earth science?

ppt slide 3:



Volcanic Eruption Images

Many of us teach our students something about volcanoes. Look at these images. These three images show a volcano before, during, and after it erupts. The volcano is Mount Saint Helens in Washington State. Let's consider the different ways of understanding these images that are appropriate for your students. For example, we might ask a student to *explain* why Mt. St. Helens is a volcano. That is one level of understanding. Think about that for a minute. As science teachers, we are very familiar with this type of understanding. We frequently ask students to *explain* why or how phenomena occur. However, we might also want students to *apply* an understanding of volcanoes to geologic formations they encounter in their lives so that they easily recognize dormant volcanoes when they see them. Explaining and applying are just two of the ways that we might ask students to *really understand* volcanoes.

ppt slide 4:



Facets of Understanding

In *Understanding by Design*, Wiggins and McTighe propose a framework for thinking about understanding. They suggest that understanding has six facets. These facets can be represented as the faces of a cube (*hold up an Understanding Cube and point to the faces*). Wiggins and McTighe propose these facets of understanding to be: explanation, interpretation, application, perspective, empathy, and self-knowledge. According to Wiggins and McTighe, a student *really* understands a concept if he or she can explain, interpret, apply, and bring perspective, empathy and self-knowledge to that concept.

Looking at Understanding Sample Narration to Accompany the PowerPoint Presentation - Page 2

ppt slide 5:



Understanding vs. Knowing

Notice how recall, identify, name...and other terms like these...are not considered facets. According to Wiggins and McTighe, *knowledge* is not the same as *understanding*. Think back to Bloom's taxonomy. Bloom described levels of thinking for which he advocated the writing of behavioral objectives. The facets of understanding reflect Bloom's higher order thinking skills.

For Wiggins and McTighe, true understanding means moving away from decontextualized, fragmented, learning and toward more purposeful, deep, and meaningful learning.

Understanding is not, "Name-that-volcano."

Understanding is not, "Draw and label a diagram showing the structure of a volcano."

Understanding is not, "Identify the type of volcano as either shield, stratovolcano, or cinder cone."

ppt slide 6:



Explanation

Let's consider each of the facets one by one. In *Understanding by Design*, Wiggins and McTighe offer the following definition of explanation:

Sophisticated and apt understandings and theories, which provide knowledgeable and justified accounts of events, actions, and ideas.

As we mentioned before, explanation is something we do a lot of in science. It is what we mean when we ask students to describe, justify, prove, show cause and effect, show the mechanism by which something works, make predictions, draw conclusions, and build theories. Explanations are central to scientific inquiry. After all, what is a hypothesis, if not a tentative explanation grounded in observation and or research? And a conclusion is an explanation that is supported by evidence.

ppt slide 7:



Explaining Volcanic Eruption

Returning to our Mt. St. Helens example and the concept of volcanic eruption, we might ask students to:

Explain why Mt. St. Helens erupted. Extend this explanation to include other volcanoes in the Cascades.

Looking at Understanding Sample Narration to Accompany the PowerPoint Presentation Page 3

ppt slide 8:



Interpretation

When Wiggins and McTighe define the facet of interpretation, it stems from a literary point of view. (*Point to the definition on the slide.*)

Narratives and translations that provide meaning.

By interpretation they mean story or narration, not simply inference or deduction like we might think of in science. Interpretation is more ambiguous than is explanation. Thinking about understanding from the facet of interpretation means telling stories. In science, these may be stories of discovery, setbacks, revolutions in understanding (i.e. paradigm shifts), perseverance in the face of obstacles, accidental insights, competition and collaboration, cheating, fraud, and misrepresentation in science, intolerance toward new ideas, misunderstanding, hostility, and ridicule.

What kinds of stories do we tell in Earth science?

ppt slide 9:



Creation Stories

We tell stories of the creation of the universe, the solar system, and the Earth.

ppt slide 10:



Geologic Stories

We tell stories of the history of the Earth, its evolution, and development.

ppt slide 11:



Earth Stories

We tell stories of the Earth's ultimate destiny and that of the universe.

John McPhee's books are examples of good Earth science stories.

Geologists often tell a story to interpret the history of a rock formation.

Looking at Understanding Sample Narration to Accompany the PowerPoint Presentation - Page 4

ppt slide 12:



Interpreting Volcanic Eruption

If we apply the facet of interpretation to Mt. St. Helens, then we might ask:

What is the geologic story of Mt. St. Helens? How has the volcano changed over time?

ppt slide 13:



Application

Application means,

The ability to use knowledge effectively in new situations and diverse contexts.

It means moving beyond inert and textbook knowledge. It means knowledge in use.

We frequently ask students to apply their knowledge in science by solving a problem, carrying out an investigation, or designing a working model.

ppt slide 14:



Applying Volcanic Eruption

Does the student who can apply the concept of volcanic eruption have an even deeper understanding than the one who can only explain or interpret the concept? *(Point to the text beneath the images on the slide.)*

Apply your understanding of the Mt. St. Helens eruption to make predictions of other places in the world where similar eruptions might occur.

ppt slide 15:



Perspective

Understanding from the facet of perspective means having

Critical and insightful points of view.

A student with perspective moves beyond an egocentric view, away from historically-limited, culturally-limited, and paradigm-limited views. He or she can think outside the box. The student sees the interconnection among things, considers multiple solutions to problems, is skeptical, gathers evidence, sees the situation from alternative viewpoints, and sees the forest as well as the individual trees.

Scientific discoveries often arise from a shift in perspective. (i.e. Watson and Crick, Einstein, etc.)

Looking at Understanding Sample Narration to Accompany the PowerPoint Presentation - Page 5

ppt slide 16:



Perspective & Volcanic Eruption

Perspective means understanding through different lenses such as,

- Looking through the lens of Earth processes and systems (i.e. Often we think that volcanoes are bad. However, they bring materials to the surface; volcanoes are good because they provide materials that enrich the soil and played a key role in the formation of Earth's atmosphere.)
- Looking through the lens of geography or location (i.e. An eruption at Yucca Mt poses different concerns than one at Mt. St. Helens.)
- Looking through the lens of topography (3-dimensional models in science help us with this lens)
- Looking through the lens of space or time (Mt. St. Helens hasn't been here forever, nor will it always be here. Have volcanoes ever erupted in this state or region?)

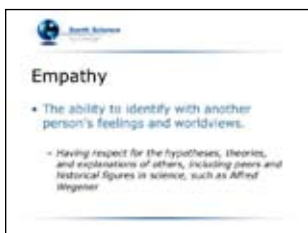
In the ESBD program, visualizations and satellite imagery tap the facet of perspective and will provide us with another lens for looking at understanding.

By providing students with opportunities to confront and grapple with multiple perspectives, such as systems, geographic, topographic, space-based, and environmental perspectives, we help them to develop insights, make discoveries, and cultivate appreciation for the complexities of our planet.

In Earth science, we want students to have a perspective that takes account of the immensity of the universe and the incredible length of geological and cosmological time.

Bacteria and other microscopic life are very important in the Earth system, yet students often have little appreciation for their importance because they are small, nearly invisible, and out of notice. By studying them, students change their perspective on the place of human life in the biosphere as a whole.

ppt slide 17:



Empathy

Empathy is

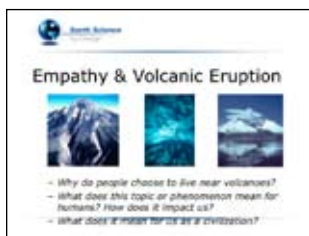
The ability to identify with another person's feelings and worldview.

Having empathy in science means having respect for the hypotheses, theories, and explanations of others, including peers and historical figures in science, such as Alfred Wegener.

This facet is not something we usually think about when teaching science and can be difficult to incorporate.

Looking at Understanding Sample Narration to Accompany the PowerPoint Presentation - Page 6

ppt slide 18:



Empathy & Volcanic Eruption

Why do people choose to live near volcanoes?

What does this topic or phenomenon mean for humans? How does it impact us?

What does it mean for us as a civilization?

The personal/societal perspective comes into play here.

ppt slide 19:



Self-Knowledge

Self-knowledge is

The wisdom to know one's ignorance and how one's patterns of thought and action inform as well as prejudice understanding.

Some ways to get at this facet are to ask students what they know, conduct a KWL (what students know, what they want to know and what they have learned) and have students critique their own work.

What do I not understand? How does this fit with other stuff I know? How well can I communicate this knowledge? How confident am I of this knowledge.

ppt slide 20:



Self-Knowledge & Volcanic Eruption

This facet of self-knowledge is about metacognition.

ppt slide 21:



Applying the Facets

Each of the topics comes from one of Earth's spheres. Apply the facets of understanding to your assigned topic.

ACTIVITY 4

What is Earth Science by Design?

Description	This activity introduces the purpose and structure of the ESBD program. Building on the previous activities, which explored the nature of understanding, it outlines for teachers the intellectual rationale of the program and describes their tasks for the two weeks of the institute. It concludes with a review of the ESBD program goals for participants and the participants' responsibilities.
Goals	<p>Completing this activity will help teachers to:</p> <ul style="list-style-type: none"> • Understand the rationale and approach of the ESBD Program • Understand their tasks for week 1 and week 2 of the summer institute • Understand their responsibilities for the entire program
Materials	<input type="checkbox"/> <i>What is ESBD?</i> PowerPoint presentation
Approximate Time	30 minutes
Procedure	<ol style="list-style-type: none"> 1. Launch the “What is Earth Science by Design?” PowerPoint presentation and emphasize that ESBD is a yearlong professional development program. While moving through the presentation, refer back to the earlier discussion on understanding and allude to the upcoming work with the Unit Planner as a template for the UBD/ESBD process. (ppt slides 1-2) 2. Point out that there are three pillars of ESBD: 1) Understanding by Design, 2) Earth as a System, and 3) Scientific Visualizations. (ppt slide 3) 3. Discuss the main features of the Understanding by Design (UBD) approach. (ppt slides 4-7) 4. Describe the Backward Design approach. The UBD approach is often referred to as “backward design”. Emphasize that backward design is not what teachers normally do; hence its name. Backward design means starting with the end in mind; that is, first figuring out what it is students should understand, know, and be able to do and then planning the learning activities to ensure that end goals are met. Participants will be asked to use backward design as they create the units they teach. (ppt slide 8)

ACTIVITY 4 What is Earth Science by Design? - Page 2

5. Briefly describe the three stages of UBD.

Mention that the first activity after lunch, “What is Worthy of Understanding?” explores the Big Ideas in Earth system science.

(ppt slide 9)

State that when teachers design their units, they will create an “authentic performance assessment” as the keystone of their assessment section.

(ppt slide 10)

Explain that Stage 3, the creation and sequencing of learning activities, is the part of the curriculum design process that they are very familiar with. However, the difference with UBD/ESBD is that every activity must be carefully chosen to guide students toward understanding and must be aligned with the goals developed in Stage 1.

(ppt slide 11)

6. Present “Earth as a System” as the second pillar of ESBD.

Explain that the final activity of today (Day 1) will introduce a systems approach to Earth science. Ask whether any of the teachers already employs a systems approach.

(ppt slide 12)

7. Introduce “Scientific Visualizations” as the third pillar of ESBD.

Explain that scientific visualizations are a fundamental tool in contemporary Earth science research. Often based on satellite imagery, they provide a new view of the Earth, which was not available forty years ago..

(ppt slide 13)

8. Provide participants with an overview of the tasks they will be undertaking during the institute.

As tasks are mentioned, answer any questions that come up.

(ppt slides 14-15)

9. Present and discuss the tasks of the ESBD program.

Emphasize that creating an ESBD unit is the key task of the institute and the program. It functions as the “authentic performance assessment” for the participants.

(ppt slide 16)

Completing daily reflections during the summer institute is an important part of participating in the program. These reflections form a journal of teachers’ professional growth and help facilitators keep learning on track.

(ppt slide 17)

ACTIVITY 4 What is Earth Science by Design? - Page 3

Point out that evaluating an ESBD unit for alignment and clarity is a key skill in becoming an effective ESBD teacher.

(ppt slide 18)

Explain that between the end of the summer institute and the fall conference, participants will work with their mentors and their partners to revise their units. At the fall conference, they will share their units and receive help to get them ready to teach.

(ppt slide 19)

Explain that implementation should happen after the fall conference.

(ppt slide 20)

Keeping an ESBD journal during implementation of the unit enables participants to take notes on implementation issues that arise and makes it easier for them to prepare the implementation report for the spring conference.

(ppt slide 21)

Peer mentoring is a valuable component of the ESBD professional development program. However, it may not be feasible or possible, given the scheduling constraints of the participating teachers.

(ppt slide 22)

Explain that implementing the unit and preparing a formal implementation report is the teachers' performance assessment for the entire ESBD program. Preparing the report and sharing it with colleagues at the spring conference is an opportunity to reflect on the implementation experience, develop ideas for improvement, and learn from colleagues.

(ppt slide 23)

10. Answer any questions teachers may have about the ESBD program.

HANDOUT 10

Reflection Day 1 Morning

Name: _____ Date: _____

Reflect on the morning's activities about the nature of understanding. Which facets do you most often use to assess student understanding in your classroom? If there is a facet that you have not used but would like to investigate further, please name it and tell why you think it would provide insights into student learning in Earth science.

ACTIVITY 5

What is Worthy of Understanding?

Description

In this activity, participants separate concepts that are central to the teaching of Earth science from those that are not. They prioritize Earth science concepts into three groups, those that are: 1) worth being familiar with, 2) important to know and do, 3) worthy of deep understanding. Sifting out what is worthy of deep understanding lays the foundation for beginning to formulate Stage 1 content of an ESBD unit. At the end of the activity, participants view the ESBD list of Big Ideas in Earth and Space Science. The organization of the list leads to a discussion of how a systems approach can be used to frame Earth science.

Goals

Completing this activity will help teachers to:

- Screen ideas to determine whether they are worthy of deep understanding
- Separate ideas that are worthy of deep understanding from those that are important to know and do and from those that are worth being familiar with.
- Become familiar with Earth system science as an organizing framework.

Materials

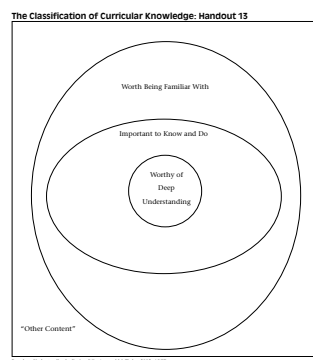
- ☐ One set of Earth science concepts per teacher group, created from *Earth Science Concepts for What is Worthy of Understanding?* Activity (Unclassified) Handout 12. Make sure each group gets a complete set, cut into strips, one concept per strip.
- ☐ Marking pens
- ☐ Cellophane tape dispensers
- ☐ A large piece of poster paper with three hand-drawn nested circles similar to *The Classification of Curricular Knowledge* Handout 13—one per group.
- ☐ *The Classification of Curricular Knowledge* Handout 13—one per small group
- ☐ *Four Filters for Enduring Understanding* Handout 14—one per teacher
- ☐ *The Big Ideas in Earth and Space Science* Handout 15—one per teacher.

Approximate Time

75 minutes

ACTIVITY 5 What is Worthy of Understanding? - Page 2

Procedure



1. **Engage teachers in a brief discussion about how what is taught in Earth science can be categorized into that which is worthy of understanding, and that which is not.**
Begin by asking if teachers can select one single idea, concept, skill, or process that is the single most important idea in Earth science (probably not!). Then ask if they think there is a set of these ideas that most could agree are more worthy of deep understanding by students, while others, even though useful, might not be quite as important. Emphasize that the “classification” of ideas is just that; it is not a scheme to throw out concepts or skills. All are worthy in some way.
2. **Introduce a classification scheme for organizing Earth science content.**
Refer participants to Handout 13 (*The Classification of Curricular Knowledge*). This is the theoretical framework that teachers will use to separate their concepts. Ask what the words “deep understanding” mean? After listening to a few responses, refer participants to Handout 14 (*Filters for Enduring Understanding*) and discuss the four defining characteristics of a concept, skill, or process that is worthy of deep understanding. Point out that while not everything that is taught for deep understanding will satisfy all four of these criteria, they should satisfy most of them.
3. **Place teachers into small groups and provide the activity directions.**
Place teachers into small groups and hand out poster paper sheets. Distribute the set of Earth science concepts on paper strips and instruct them to decide as a group whether the concept listed on each strip is either a) Worthy of deep understanding, b) Important to know or do, or c) Worth being familiar with. Then have them tape the concept in the appropriate area of their poster paper.
4. **Together with other staff members, facilitate the groups.**
If participants are struggling, ask questions to help them think through their rationales for placing concepts within particular circles.
5. **Ask participants from each group to make a five to ten minute group presentation about the way they categorized their Earth science concepts.**
After they have been given sufficient time to classify all of their concepts, give each group 5 to 10 minutes to summarize their results, using their poster paper as a visual. Instruct each group to pick out several of their “Worthy of deep understanding” strips and explain how each satisfies the four criteria for enduring understanding.
6. **Relate deep understandings to the list of Big Ideas in Earth and Space Science.**
Tell teachers that the concepts or processes they have just classified were organized in a particular way. Ask them if they can identify the organizational scheme that was used. Hand out the ESBD list of Big Ideas and review its layout and content. Ask, “Are there other spheres that might have been omitted?” (Some think that the cryosphere [ice] should be included as one of the spheres). Discuss the sections, “Earth as a System” and “The Nature of Science.” The Nature of Science includes and subsumes many habits of mind and processes involved in scientific endeavors.

HANDOUT 11

Earth Science Concepts for “What is Worthy of Understanding?”

(Answer Key for Leaders)

Classified by Sphere and by Curricular Importance

- 1 = Worthy of Deep Understanding
 2 = Important to Know and Do
 3 = Worth Being Familiar With

Atmosphere

- 1 – Solar radiation drives the atmosphere, causing winds and powering the hydrologic cycle.
- 1 – The atmosphere is a mixture of gases and suspended solids and liquids.
- 1 – The atmosphere exhibits long-term circulation patterns and short-term patterns known as weather-storms, hurricanes, and tornadoes.
- 2 – Clouds are formed when a rising then cooling air mass reaches the dew point.
- 2 – Weather instruments are used to measure elements of weather such as temperature, air pressure, precipitation, and wind speed.
- 2 – Air has mass and for this reason has other properties including pressure and density.
- 3 – To find °F, multiply °C by 1.8, then add 32.
- 3 – The Earth’s atmosphere is .03% CO₂.
- 3 – Lines of equal pressure on a weather map are called isobars.

Biosphere

- 1 – Human beings have a unique, large, and growing impact on the Earth’s biosphere.
- 1 – Environmental change can cause extinction or lead to the evolution of a species.
- 1 – Life affects the composition of the atmosphere, weathering, the carbon cycle, and the rock cycle.
 - A species is a population of organisms that are able to interbreed and produce fertile offspring.
- 2 – Many different kinds and numbers of organisms have existed at various times during Earth’s history.
- 2 – There are two kinds of natural resources, renewable and nonrenewable.
- 3 – An asteroid impact probably caused the extinction of the dinosaurs 65 million years ago.
- 3 – Anthracite coal is an important natural resource.
- 3 – Soils are made of layers called horizons.

Space Science

- 1 – The relative positions of the sun, Earth, and moon account for the phases of the moon.
- 1 – The seasons are caused by the relative position of the Earth’s axis as it revolves around the sun.

HANDOUT 11 Earth Science Concepts for "What is Worthy of Understanding?" Activity - Page 2

- 1 – The Earth is just one planet in a solar system, in a galaxy filled with billions of stars, in a universe of billions of other galaxies.
- 2 – Galaxies are large assemblages of different types of stars.
- 2 – Lunar and solar eclipses are created by particular (and rare) alignments of the sun and moon.
- 2 – When the moon is full or new, neap and spring tides can be expected.
- 2 – The scale relationships of the Earth, sun and moon are important for the understanding of astronomical events and processes.
- 3 – The Earth has a very slight elliptical orbit (almost a perfect circle).
- 3 – When only a part of the sun is covered by the moon during a solar eclipse, it is called a partial eclipse.
- 3 – A light year is about 6 trillion miles.

Geosphere

- 1 – The movement of lithospheric plates causes slow changes in the Earth's surface (mountains, ridges, ocean basins).
- 1 – The Earth's surface is built up and worn down by natural processes, such as rock formation, erosion, and weathering.
- 2 – Fossils and radioactive dating provide evidence used to interpret Earth's evolution.
- 2 – Over millions of years the continuous movement of the Earth's crust causes the continents to merge and divide repeatedly.
- 2 – Most of the world's earthquake and volcanoes occur at the boundaries of lithospheric plates.
- 3 – Superposition helps us determine the sequence of geologic events.
- 3 – The action of freezing and thawing that breaks down the surface of rocks is called frost wedging.
- 3 – The pattern of volcanic activity around the Pacific basin is called the "Ring of Fire."

Hydrosphere

- 1 – Circulation patterns in the oceans are driven by density differences and wind.
- 1 – Water cycles through the atmosphere, hydrosphere, geosphere, and biosphere.
- 2 – Large canyons, mountains, and long ridges can be found on the floor of Earth's oceans.
- 2 – The Gulf Stream causes local and regional climate variations in different parts of the world.
- 3 – The West Wind Drift near Antarctica is a global current.
- 3 – The salinity of Earth's oceans is roughly constant over time.

HANDOUT 12

Earth Science Concepts for "What is Worthy of Understanding?"

Unclassified

Print several sheets of these (one-sided) and cut apart individual concepts with a paper cutter. Give one complete set to each small group of teachers.

Solar radiation drives the atmosphere, causing winds and powering the hydrologic cycle.

The atmosphere is a mixture of gases and suspended solids and liquids.

The atmosphere exhibits long-term circulation patterns and short-term patterns known as weather: storms, hurricanes, and tornadoes.

Clouds are formed when a rising then cooling air mass reaches the dew point

Weather instruments are used to measure elements of weather such as temperature, air pressure, precipitation, and wind speed.

Air has mass and for this reason has other properties including pressure and density.

To find °F, multiply °C by 1.8, then add 32.

The Earth's atmosphere is .03% CO₂.

Lines of equal pressure on a weather map are called isobars.

Human beings have a unique, large, and growing impact on the Earth's biosphere.

Environmental change can cause extinction or lead to the evolution of a species.

Life affects the composition of the atmosphere, weathering, the carbon cycle, and the rock cycle.

HANDOUT 12 Earth Science Concepts for "What is Worthy of Understanding?" Activity - Page 2

A species is a population of organisms that are able to interbreed and produce fertile offspring.

Many different kinds and numbers of organisms have existed at various times during Earth's history.

There are two kinds of natural resources, renewable and nonrenewable.

An asteroid impact probably caused the extinction of the dinosaurs 65 million years ago.

Anthracite coal is an important natural resource.

Soils are made of layers called horizons.

The relative positions of the sun, Earth, and moon account for the phases of the moon.

The seasons are caused by the relative position of the Earth's axis as it revolves around the sun.

The Earth is just one planet in a solar system, in a galaxy filled with billions of stars, in a universe of billions of other galaxies.

Galaxies are large assemblages of different types of stars.

Lunar and solar eclipses are created by particular (and rare) alignments of the sun and moon.

When the moon is full or new, neap and spring tides can be expected.

The scale relationships of the Earth, sun and moon are important for the understanding of astronomical events and processes.

The Earth has a very slight elliptical orbit (almost a perfect circle).

When only a part of the sun is covered by the moon during a solar eclipse, it is called a partial eclipse.

HANDOUT 12 Earth Science Concepts for "What is Worthy of Understanding?" Activity - Page 3

A light year is about 6 trillion miles.

The movement of lithospheric plates causes slow changes in the Earth's surface (mountains, ridges, ocean basins).

The Earth's surface is built up and worn down by natural processes, such as rock formation, erosion, and weathering.

Fossils and radioactive dating provide evidence used to interpret Earth's evolution.

Over millions of years the continuous movement of the Earth's crust causes the continents to merge and divide repeatedly.

Most of the world's earthquake and volcanoes occur at the boundaries of lithospheric plates.

Superposition helps us determine the sequence of geologic events.

The action of freezing and thawing that breaks down the surface of rocks is called frost wedging.

The pattern of volcanic activity around the Pacific basin is called the "Ring of Fire."

Circulation patterns in the oceans are driven by density differences and wind.

Water cycles through the atmosphere, hydrosphere, geosphere, and biosphere.

Large canyons, mountains, and long ridges can be found on the floor of Earth's oceans.

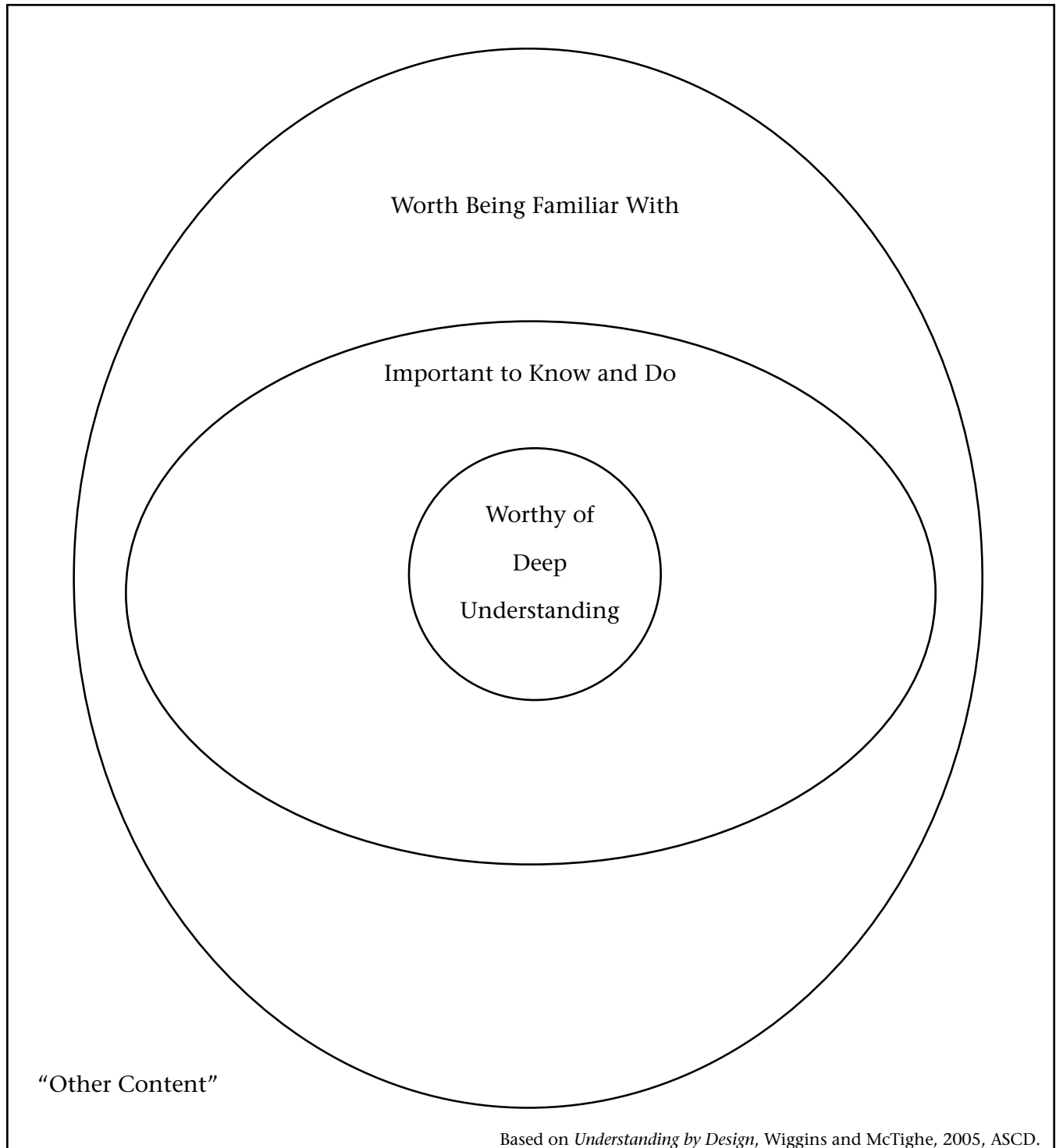
The Gulf Stream causes local and regional climate variations in different parts of the world.

The West Wind Drift near Antarctica is a global current.

The salinity of Earth's oceans is roughly constant over time.

HANDOUT 13

The Classification of Curricular Knowledge



HANDOUT 14

Filters for Enduring Understanding

Use these filters to determine if an idea, concept, or process is worthy of deep understanding. If you can answer “yes” to each of these questions, then it is.

1. Does the idea have enduring value over time?

2. Does the idea reside at the heart of the discipline?

3. Is the idea rich in meaning, integrative, complex, and in need of uncoverage to be understood?

4. Does the idea help the student organize and make sense of the content?

HANDOUT 15

The Big Ideas in Earth and Space Science

The Earth System

1. Earth can be conceived as an interacting set of processes and structures composed of the atmosphere, geosphere, hydrosphere, and biosphere.
2. Radiation, conduction, and convection transfer energy through Earth's systems.

The Geosphere

3. The geosphere includes the lithosphere, the mantle, and the dense metallic cores.
4. The surface of Earth has identifiable major features—land masses (continents), oceans, rivers, lakes, mountains, canyons, and glaciers
5. The movement of Earth's lithospheric plates causes both slow changes in the Earth's surface (e.g., formation of mountains and ocean basins) and rapid ones (e.g., volcanic eruptions and earthquakes).
6. Earth's surface is built up and worn down by natural processes, such as rock formation, erosion, and weathering.
7. Physical evidence, such as fossils and radioisotopic dating, provide evidence for the Earth system's evolution and development.

The Atmosphere

8. The atmosphere is a mixture of gases with suspended solids and liquids.
9. Radiant energy from the sun creates temperature differences in water, land, and the atmosphere which drive local, regional, and global patterns of atmospheric circulation.
10. The atmosphere exhibits long-term circulation patterns (climate) and short-term patterns known as weather—storms, hurricanes, and tornadoes.

The Hydrosphere

11. Water cycles through the atmosphere, hydrosphere, geosphere, and biosphere.
12. Circulation patterns in the oceans are driven by density differences and by exchange of momentum with the atmosphere.
13. Liquid water in great abundance makes Earth unique among the planets of the solar system.

The Biosphere

14. Life is pervasive throughout the Earth system—in the atmosphere, the hydrosphere, and the upper lithosphere.
15. Life appeared early in Earth's history and is intimately involved in the nature of Earth—i.e. composition of the atmosphere, weathering, carbon cycle, and rock cycle.
16. The biosphere both shapes and is shaped by the physical environment.
17. Human beings have a unique, large, and growing impact on Earth systems.

Space Science

18. Earth exists in the solar system, in the Milky Way galaxy, and in the universe, which contains many billions of galaxies.
19. The sun, Earth, and the other planets were formed in a few hundred million years between four and five billion years ago.
20. The relative position and movements of Earth, the moon, and sun account for day and night, lunar and solar eclipses, the observed moon phases, tides, and seasons.

The Nature of Earth Science

21. Earth scientists use representations and models, such as contour maps and satellite images to help them understand Earth systems.
22. Scientists use quantitative, qualitative, experimental and other methods of investigation to understand Earth.
23. Earth scientists make an assumption of uniformitarianism, that the processes that shaped Earth in the past are the same processes we observe today.
24. Technological advances, such as seismic sounding and satellite remote sensing, advance Earth science knowledge.
25. As in all scientific disciplines, knowledge in Earth science is subject to revision.

ACTIVITY 6

An Introduction to Earth System Science

Description

This activity helps teachers develop an understanding of Earth as a set of closely coupled systems. Teachers make connections between environmental data to see the interplay among the many processes that take place on varying spatial and chronological scales.

The processes that comprise the global environment are interconnected. Understanding how these processes operate on a global basis is to understand the Earth as a system. Understanding Earth as a system – Earth System Science – requires a qualitative and quantitative exploration of the connections among all parts of the system.

Earth system science focuses on the processes taking place in the atmosphere, oceans, fresh water bodies, ice, soils, and vegetation growing on the land surface. It involves making connections between the soil and atmosphere, plus energy from the sun, and the gases and particles entering the atmosphere and oceans from space or from the layers of molten and solid rock beneath Earth's surface. Many of these processes involve life, so Earth system science makes connections between these physical processes and the places on Earth where organisms live.

Goals

Completing this activity will help teachers to:

- Identify global patterns and connections in environmental data.
- Understand Earth as an integrated system of components and processes.

Materials

- ☐ One *GLOBE Earth System Poster: Exploring Connections in a Typical Year* (Go to www.globe.gov for information on obtaining a copy.) The poster is also available from NASA CORE, <http://education.nasa.gov> as Item 300.1-10P for \$6.00.
- ☐ *Dr. Art's Guide to Planet Earth*, at least one copy per small group (available at <http://www.planetguide.net>)

Approximate Time

60 minutes

Advance Preparation

Cut the GLOBE Earth System Poster into the following sections: (The cards and labels can also be found as printable color pdfs on the ESBD website and Resource CD)

- 6 “measurement” labels (Solar Energy, Average Temperature, Cloud Cover, Precipitation, Soil Moisture, Vegetation)
- 6 “month” labels (January, March, May, July, September, November)
- 36 “Earth system cards” (6 Solar Energy cards, 6 Average Temperature cards, 6 Cloud Cover cards, 6 Precipitation cards, 6 Soil Moisture cards, 6 Vegetation cards)

Laminating the labels and cards makes them easier for participants to use and reduces wear.

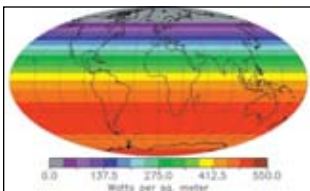
ACTIVITY 6 An Introduction to Earth Systems Science - Page 2

Procedure

Activity 1– Exploring a Single Map

1. Arrange teachers into 6 groups of 2-3 persons each. Provide each group with a measurement label for one of the measurement types.

Group	Measurement Label
One	Solar Energy
Two	Average Temperature
Three	Cloud Cover
Four	Precipitation
Five	Soil Moisture
Six	Vegetation



2. Select six Earth system cards, one from each measurement type. Distribute one card to each group which has the corresponding measurement label. (Each group will have a card showing a different measurement.)
3. Instruct the groups to study and interpret their own card. Use the following guiding questions:
 - What is the range of values shown on the scale bars on your card?
 - Where in the world do you find the highest and lowest values of the data on your map? Where are the extremes? Why are the extremes in these locations and not somewhere else?
 - Do you see any patterns? Are they different on different continents? Different over water than over land? How do you explain these patterns?
4. Ask the groups to share with the whole group the information conveyed on their card. Use the guiding questions to facilitate the discussion, but encourage groups to report on other aspects of the information not covered by the questions.

Activity 2 – Exploring Annual Changes in a Measurement

1. Distribute the other five Earth system cards for each measurement type to the corresponding group of teachers so that they now have a complete annual set.
2. Instruct the groups to put the cards in chronological order, starting with January.
3. Ask the groups to identify annual cycles for their measurements. Use the following guiding questions:
 - What changes do you see through the year? What seasonal changes and annual cycles emerge? What explanations can you suggest for these patterns?
 - Pick a location or area. During which months do the extreme highs and lows occur for each measurement? What explanations can you suggest for the timing of those extremes?

ACTIVITY 6 An Introduction to Earth Systems Science - Page 3

- Which regions experience the extreme highs and lows for each measurement? Which regions don't experience the extremes? Why do you think this is so?
 - What differences, if any, do you find between the year's variations over the oceans versus the year's variations over the continents?
 - Are there regions that remain unchanged over the year? Why do you think this is so?
4. After a few minutes, ask each group to share with the whole group their discoveries of patterns and their interpretations of those patterns.

Activity 3 – Exploring Relationships Between Two Types of Measurements

1. Instruct groups to come together in the following pairs:
 - Group One (**Solar Energy**) with Group Two (**Average Temperature**),
 - Group Three (**Cloud Cover**) with Group Four (**Precipitation**),
 - Group Five (**Soil Moisture**) with Group Six (**Vegetation**).
2. Have groups put their cards in chronological order for each type of measurement.
3. Have groups line their measurement cards next to each other.
4. Ask groups to identify the relationships and associations between the measurements. Use the following guiding questions:
 - What relationship do you see between solar energy and average temperature? Cloud cover and precipitation? Soil moisture and vegetation?
 - Are the relationships proportional or inverse?
5. After a few minutes, ask each group to share with the whole group the relationships they have identified between the measurements. Have them also share the methods they used to identify these relationships.

Activity 4 – What is Earth System Science?

1. Refer teachers to *Dr. Art's Guide to Planet Earth*.
2. Ask teachers to work in small groups to relate the following systems questions from Dr. Art's book to the preceding activities:
 - In terms of the components that Dr. Art uses to conceptualize the Earth system, what parts did you examine during the activities?
 - Which of these parts has to do with Earth's matter? Which of these parts has to do with Earth's energy? Which of these parts has to do with Earth's life?
 - How do the parts work together to create the Earth system as a whole?
 - Which of the parts can be considered a closed system, which ones can be considered open systems?
 - What are the parts of each of the smaller systems that you examined in this activity?

HANDOUT 16**An Introduction to Earth System Science****Guiding Questions for Small Groups:****Activity 1 – Exploring a Single Map**

- What is the range of values shown on the scale bars on each card?
- Where in the world do you find the highest and lowest values of the data on your map? Where are the extremes? Why are the extremes in these locations and not somewhere else?
- Do you see any patterns? Are they different on different continents? Different over water than over land? How do you explain these patterns?

Activity 2– Exploring Annual Changes in a Measurement

- What changes do you see through the year? What seasonal changes and annual cycles emerge? What explanations can you suggest for these patterns?
- Pick a location or area. During which months do the extreme highs and lows occur for each measurement? What explanations can you suggest for the timing of those extremes?
- Which regions experience the extreme highs and lows for each measurement? Which regions don't experience the extremes? Why do you think this is so?
- What differences, if any, do you find between the year's variations over the oceans versus the year's variations over the continents?
- Are there regions that remain unchanged over the year? Why do you think this is so?

Activity 3 – Exploring Relationships Between Two Types of Measurements

- What relationship do you see between solar energy and average temperature? Cloud cover and precipitation? Soil Moisture and Vegetation?
- Are the relationships proportional or inverse?

Activity 4 – What is Earth System Science?

- What are the parts of the Earth system that you examined during the activities?
- Which of these parts has to do with Earth's matter? Which of these parts has to do with Earth's energy? Which of these parts has to do with Earth's life?
- How do the parts work together to create the Earth system as a whole?
- Which of the parts can be considered a closed system, which ones can be considered open systems?
- What are the parts of each of the smaller systems that you examined in this activity?

HANDOUT 18

Reflection Day 1 Afternoon

Name: _____ Date: _____

What is the main understanding that you struggled with today?

Please share any insights that you gained today about teaching and learning.

Please share any thoughts about the activities that you felt were particularly helpful or confusing.
Be as specific as possible.

DAY 2

Introduction

Day 2 Overview

Participants work in teams to design a sample unit following the UBD/ESBD model. The morning activities focus on Stage 1. The afternoon activities focus on Stage 2. In the morning, participants work in small teams to design Stage 1 of a Rock Cycle unit. In the afternoon they design an authentic performance assessment and a rubric to evaluate it.

Day 2 Schedule

8:30-8:45	Welcome and overview of the day
8:45-9:30	Designing an ESBD Unit: Enduring Understandings
9:30-10:15	Designing an ESBD Unit: Essential Questions
10:15-10:30	Break
10:30-11:30	Designing an ESBD Unit: Knowledge, Skills, and Typical Misunderstandings
11:30-11:45	Reflection
11:45-12:45	Lunch
12:45-1:15	Introducing Assessment
1:15-2:00	Designing Performance Assessments
2:00-2:15	Break
2:15-3:15	Creating Rubrics
3:15-3:30	Reflection

ACTIVITY 7

Designing an ESD Unit: Identifying Understandings

Description

This activity and the two following activities help teachers deepen their understanding of the UBD/ESBD unit design process by working through the design of a sample unit focused on the rock cycle. They alternate between working in small groups to generate and discuss ideas and come together as a whole group to share, debate, and reach consensus on a common Stage 1 for The Rock Cycle.

This activity helps teachers to identify understandings—the first task of Stage 1 of designing an ESD unit. In Activity 8, they frame essential questions that help guide and uncover the enduring understandings. In Activity 9, they identify the specific knowledge and skills that students will need, and they try to identify potential areas of student misunderstanding. At the end of these three activities each team of teachers will have completed an abbreviated version of the Stage 1 of the UBD process for a unit on the rock cycle. They will use their results to begin Stage 2.

Expect teachers to experience a great deal of satisfaction from their initial unit design work. By working in teams they gain strength from each other. Try to form groups that will work well together. Group teachers by grade level if possible and try to make sure each group has at least one teacher with strong content knowledge. It also is good to make sure each group has at least one highly experienced teacher. It is not clear whether to put teachers from the same school in the same group or to spread them around. At this stage, it probably is good to give them exposure to new teachers in the group rather than to put them with teachers they already know. Keep the same groups together for the work on Stage 1 (Activities 7, 8, and 9). Then create new groupings for Stage 2 and for Stage 3 so that teachers have a chance to work with many others.

It is important to have one projection-equipped computer connected to the Internet in order to access the ESD web site and use the Unit Planner. At the end of each phase of work, conduct a whole-group discussion and reach a consensus on the unit content that goes into the Unit Planner for the whole group. The whole group creates only one sample unit. However, one member of each group should enter the “consensus unit” into the Unit Planner for their group. Having all the units the same helps the groups stay together rather than creating four units that have slightly different sets of enduring understandings, essential questions, knowledge and skills, etc.

Goals

Completing this activity will help teachers to:

- Design Stage 1 of a unit using the UBD/ESBD process.
- Screen ideas to determine whether they are worthy of deep understanding.

ACTIVITY 7 Designing an ESD Unit: Identifying Understandings - Page 2

Materials

- ☐ Computers connected to the Internet – at least one for each group and one connected to the projection device
- ☐ The Earth Science by Design web site (www.esbd.org)
- ☐ *ESBD Unit Planner* Handout 19
- ☐ *The Rock Cycle in the NSES* Handout 20
- ☐ *The Classification of Curricular Knowledge* Handout 13
- ☐ *Questions to Screen for Deep Understanding* Handout 14
- ☐ *Understandings for the Rock Cycle* Handout 21
- ☐ Note cards for writing down ideas

Approximate Time

45 minutes

Procedure

Organize the teachers into small teams of 3, 4, or 5. These teams will stay together to complete the entire sample unit on the rock cycle. Assign a staff facilitator to each group.



1. Introduce the activity

Explain that this activity and the two that follow it (Activities 8 & 9) will enable teachers to gain practice designing an ESD unit in a collaborative process.

Remind teachers that during the second week of the institute, they will create an Earth science unit that they will teach. The activities for the rest of this week will help them get ready for that by giving them practice in the design process using the rock cycle as their “big idea.”

2. Review the three stages of UBD/ESBD.

Refer teachers to *ESBD Unit Planner* Handout 19. Emphasize that the design process is an iterative one. Explain that in this activity participants will focus on Stage 1. They will design a unit for the rock cycle, using the four parts of Stage 1 of the Unit Planner—understandings, essential questions, knowledge and skills, and student misunderstandings.

Explain that today and tomorrow they will have an opportunity to work through all three stages of the design process, focusing on the rock cycle, a core topic in Earth science. Explain that even though this process is presented in a step-by-step manner, it is an iterative process, in which the designer cycles back to make changes in the design later on. The Unit Planner helps keep the design organized.

ACTIVITY 7 Designing an ESD Unit: Identifying Understandings - Page 3

3. Present the National Science Education Standard on the rock cycle.

Refer teachers to Handout 20. Explain that the rock cycle is “big idea.” It is an idea that is central to Earth science. Furthermore, many of them will teach about the rock cycle as a regular part of their curriculum. Big ideas are the starting point of the ESD/UBD process. Explain that big ideas can come from National Standards, State level, or district standards. Big ideas, like the rock cycle, come up repeatedly in the study of a subject area.

4. Explain the process teachers will use to come up with enduring understandings for the rock cycle.

Refer participants to Handout 13 (*The Classification of Curricular Knowledge*), Handout 14 (*Filters for Deep Understanding*), and Handout 20 (*The Rock Cycle in the NSES*). Tell teachers that in this activity they are to design a unit on the rock cycle for middle school Earth science. In order to do this, they will first need to identify the understandings that lie at the core of the big idea “rock cycle.” They will then proceed in later activities to identify essential questions, knowledge, skills, and possible student misunderstandings.

Working in small teams, they will generate a large quantity of ideas that capture the understanding they want students to have of the rock cycle. Then they will classify these ideas into 3 groups:

1. Worth being familiar with,
2. Important to know and do,
3. Worthy of deep understanding.

They will use Handout 13, *The Classification of Curricular Knowledge*, to help them do this.

Explain that they will then also check to make sure that each nominated “enduring understanding” can pass through each of four filters (Refer to Handout 14, *Filters for Enduring Understanding*):

1. Does the idea have enduring value over time?
2. Does the idea reside at the heart of the discipline of Earth science?
3. Is the idea rich in meaning, integrative, complex, and in need of uncoverage to be understood?
4. Does the idea help the student organize and make sense of the content?

Explain that they should think of this as a brainstorming activity, in which they come back later to critique the ideas initially put forth. They should not throw away ideas they generate, because even though they may decide that the ideas are not “enduring understandings”, they may be “important to know and do” or “worth being familiar with.” They may be able to use them in a later part of the Stage 1 design work when they describe the knowledge and skills that underpin the enduring understandings.

ACTIVITY 7 Designing an ESD Unit: Identifying Understandings - Page 4

5. Place teachers into small groups and facilitate the discussions.

Be sure that each understanding that is nominated as “enduring” is vetted. Have teachers brainstorm enduring understandings for the rock cycle and write them on cards or paper. They should discuss them and test them against the four filters. Each group should end up with from two to four understandings that they feel are worthy of deep understanding. They should record them on Handout 21 (*Understandings for the Rock Cycle*).

6. Reconvene the small groups into one large group and share.

Have one member from each team share their group’s enduring understandings. Write these understandings on a whiteboard or overhead, or type them up on a computer connected to a projector so that they everyone can easily view them.

7. Conduct a discussion about whether the listed ideas are “enduring.”

Try to reach a consensus within the whole group on whether the understandings should be accepted as “worthy of deep understanding”, narrowing the list to two to four enduring understandings for the rock cycle. Some groups will actually have come up with the same understandings, but with slightly different wording. In other instances, teachers may feel particularly strongly about their nominated enduring understanding. Facilitate the process to arrive at a small consensus set of two to four enduring understandings. Explain that when each of them creates their own units, then they will each most likely have unique enduring understandings.

8. Have one member of each group enter the final understandings into their online Unit Planner along with the “big idea” it teaches.

Notes

The rock cycle was chosen as the topic for the practice unit, because it is central to Earth science and because most middle school Earth science curricula teach about rocks in some way. As needed, substitute another “big idea” that may be more appropriate for teachers in your program.

HANDOUT 19

ESBD Unit Planner

Title:

Author:

School:

Stage 1: Identify Desired Results

Unit Description:

Relationship to the Big Ideas in Earth Science:

Unit Enduring Understandings:

Unit Essential Questions:

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

What students typically misunderstand:

Stage 2: Determine Acceptable Evidence

Describe the authentic performance assessment in terms of GRASPS.

G

What is the Goal of the performance?

R

What Role does the student assume in the performance?

A

What Audience does the student address?

S

What is the Situation for the performance?

P

What Product should be produced?

S

What are the Standards for the product?

Preconceptions Survey:

Describe how determine students' pre-existing level of understanding before you begin the unit.

Quizzes, Tests, and Academic Prompts:

Describe any quizzes, test, or academic prompts you will use to assess students' understanding.

Other Assessment Evidence:

Describe any other evidence you will use to assess student understanding, e.g. portfolios, class discussions

Stage 3: Plan Learning Experiences, Instruction, and Resources

Use "WHERE TO" as a guide to describe the sequence of learning experiences, instructional strategies, and resources you will use to help students address the essential questions of the unit and achieve deep understanding of the big ideas.

W

How will you help students know *where* they are headed in this unit and *why* and what are the major assignments, performance tasks, and criteria by which the work will be judged)?

H

How will you *hook* students through engaging and thought-provoking experiences (e.g., issues, oddities, problems, and challenges) that point toward big ideas, essential questions, and performance tasks?

E

What events, real or simulated, can students *experience* to make the ideas and issues real? What learning activities will help students to *explore* the big ideas and essential questions? What instruction is needed to *equip* students for the final performances?

R

How will you cause students to *reflect* and *rethink* to dig deeper into the core ideas? How will you guide students in *rehearsing*, *revising*, and *refining* their work based on feedback and self-assessment?

E

How will students *exhibit* their understanding about their final performances and products? How will you guide them in *self-evaluation* to identify the strengths and weaknesses in their work and set future goals?

T

How will you *tailor* and differentiate instruction to accommodate your student's developmental needs, learning styles, prior knowledge, and interests?

O

How will you *organize* a sequence of learning experiences that will best develop and deepen student understanding, while minimizing likely misconceptions?

HANDOUT 20**The Rock Cycle in the NSES**

“Some changes in the solid Earth can be described as the ‘rock cycle.’ Old rocks at the Earth’s surface weather, forming sediments that are buried, then compacted, heated, and often recrystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues.”

National Science Education Standards (1996), Content Standard D, grades 5-8, p. 160.

HANDOUT 21

Understandings for The Rock Cycle

List the 2-4 understandings that your group selected for the Rock Cycle unit . (They must have passed four screening questions.)

1.

2.

3.

4.

Group Members _____

ACTIVITY 8

Designing an ESBD Unit: Essential Questions

Description This activity helps teachers to create essential questions—the second task of Stage 1.

Goals Completing this activity will help teachers to:

- Recognize the role of essential questions in teaching and learning.
- Distinguish essential from non-essential questions.
- Design Essential Questions for Stage 1 of a unit using the UBD/ESBD process.

Materials

- ☐ *Characteristics of Essential Questions* Handout 22
- ☐ *Essential Questions for the Rock Cycle* Handout 23
- ☐ Note cards for writing down essential questions

Approximate Time 45 minutes

Procedure

- 1. Introduce the topic of essential questions.**
 Explain that while the understandings that they created in Activity 7 are the end point of the backward design process, essential questions are the starting point.
 Say something like:
 We have just finished reaching consensus on some enduring understandings for the rock cycle unit. That means that we now know rather precisely what we want students to understand. So what is the next step in designing a unit? Do we just tell them the answers? Of course not. We know that students retain very little of what they are told. Instead, the strategy that Wiggins and McTighe propose and that we are following in ESBD is to look for some really interesting questions that have the enduring understandings as their answers. We call these questions that are tied to, that are derived from, the enduring understandings, the “essential questions.” These are the questions that will guide students toward deep and enduring understanding.
 The understandings are where you end up. The questions are where you begin. This is the essence of “backward design!” We start with the destination and then “back up” by asking, “What takes us there?” What questions drive us to these conclusions?
- 2. Refer teachers to Handout 22 (*Characteristics of Essential Questions*) and discuss the nature of essential questions.**
 Say something like:
 Wiggins and McTighe quote Jerome Bruner, “Given particular subject matter or a particular concept, it is easy to ask trivial questions....It is also easy to ask impossibly difficult questions. The trick is to find the medium questions that can be answered and that can take you somewhere.” (*The Process of Education*, 1960, pg. 40; cited in *Understanding by Design*, 2005, pg. 105)

ACTIVITY 8 Designing an ESBD Unit: Essential Questions - Page 2

Emphasize that while most of them have a great deal of experience writing test questions, essential questions are substantially different, and much broader than the types of questions that we usually ask students.

They are complex, often counterintuitive, and may be provocative. They are intentionally designed to help reveal the richness and depth of a subject.

3. Share some examples of essential questions from Earth Science by Design units.

Why does the wind blow?

We cannot step in the same river twice. Why?

Does a mountain last forever? What can a mountain tell us about Earth?

What would Earth be like if there was no wind?

How did the theory of plate tectonics evolve? Why is this theory a revolution?

4. Brainstorm essential questions to accompany the enduring understandings that were agreed upon for the rock cycle.

In the same small groups as in Activity 7, have teachers write down essential questions onto note cards. Remind teachers to test each candidate essential question against the list of characteristics (Handout 22). Have them discuss their candidate questions and come to a group consensus. They should then record, at least two, but not more than four, essential questions onto Handout 23 (Essential Questions for the Rock Cycle).

5. Share the results of brainstorming.

Reconvene the small groups into one large group and have one member from each team share their group's essential questions. Write these questions on a whiteboard or overhead, or type them up on a computer connected to a projector so that they everyone can easily view them.

6. Conduct a discussion about whether the questions listed are "essential".

Facilitate the discussion, referring as needed to Handout 23, in order to arrive at a group consensus on two to four essential question that are directly tied to the enduring understandings for the rock cycle. Once again, explain that when each participant creates their own units, they will most likely, write unique essential questions.

7. Have one member of each group enter the final essential questions into their online Unit Planner.

Notes

During the process of brainstorming and discussing essential questions, the issue of "intent" of a question may come up. For example, "What is a rock?" could, in fact, be an essential question, if the designer, intends for the question to elicit deep understanding, rather than factual knowledge.

HANDOUT 22

Characteristics of Essential Questions

In their book *Understanding by Design* (2005), Grant Wiggins and Jay McTighe develop the concept of essential questions. Here is a short summary of the nature and purpose of essential questions:

- Essential questions help guide teaching and learning.
- They engage students (so they must be interesting!)
- They should not have easy, quick, or obvious answers.
- They should not be able to be answered with a simple factual statement.
- They should require and invite elaboration.
- They may be counter-intuitive.
- They may be provocative.
- They may force a change of perspective.
- They may encourage empathy.
- Teachers and students should return to them over and over during the course of their study on a topic.
- Essential questions should be “provocative and multilayered questions that reveal the richness and complexities of a subject”.
- They point to the “key inquiries and the core ideas of a discipline”.
- Essential questions should raise other important questions.

HANDOUT 23

Essential Questions for The Rock Cycle

List the 2-4 essential questions for the Rock Cycle that your group selected.

1.

2.

3.

4.

Group Members _____

ACTIVITY 9

Designing an ESD Unit: Knowledge, Skills, and Typical Misunderstandings

Description

This activity helps teachers to identify the knowledge and skills students need—the third task of Stage 1 of designing an ESD unit—and identify typical misunderstandings that students might have. The product of this activity is a consensus list of knowledge and skills students will need in order to answer the essential questions and attain deep and enduring understanding plus an “educated guess” about what students typically misunderstand regarding the rock cycle. One member of each group will enter these into the Unit Planner. At the end of this activity the group of teachers will have completed an abbreviated version of the Stage 1 of the UBD process for a unit on the rock cycle. They will use their results to begin Stage 2 in Activity 11

Goals

Completing this activity will help teachers to:

- Identify the knowledge and skills required for the understandings and essential quest of a unit.
- Identify what students typically misunderstand.

Materials

- ☐ *Knowledge and Skills for the Rock Cycle* Handout 24
- ☐ *Potential Misunderstandings in the Rock Cycle* Handout 25
- ☐ Note cards for writing down knowledge and skills

Approximate Time

45 minutes

Procedure

1. Introduce the topic of knowledge and skills.

Explain that knowledge and skills are the fundamental concepts and ideas that underlie and build toward deep understanding. In addition, the design process recognizes that students may misunderstand some of these concepts.

Say something like:

Now we are going to get more specific. We have identified the enduring understandings and the essential questions, though we reserve the right to go back and change them. Now we want to write down the specific knowledge and skills that students will need in order to address the essential questions and build toward the enduring understandings. We also want to consider the potential misunderstandings that students may bring to the unit or that they even may retain after studying the unit.

Remember, this is not the time to think about how students will acquire this knowledge and these skills, nor the time to think about learning activities—that is the work of Stage 3. Consider only what students need to know, not how they will learn it or how you will teach it. It will be hard not to leap into ideas for how you will teach these concepts, but it is very important that you not do so yet.

ACTIVITY 9 Designing an ESD Unit: Knowledge, Skills, and Typical Misunderstandings - Page 2

2. Brainstorm lists of knowledge, skills, and typical misunderstandings for the rock cycle.

Refer participants to Handout 24 and Handout 25. In the same small groups as in Activity 8, have teachers brainstorm and write down their ideas directly onto the handouts. Encourage the groups to try to limit their knowledge and skills list to five that are the most relevant and to limit their misunderstandings to about eight.

3. Share the results of brainstorming.

Reconvene the small groups into one large group and have one member from each team share their group's knowledge and skills. Write these questions on a whiteboard or overhead, or type them up on a computer connected to a projector so that they everyone can easily view them.

4. Relate the knowledge and skills to the enduring understandings and essential questions.

Discuss the relationship of each knowledge or skill to the enduring understandings and essential questions that have been agreed upon for the rock cycle. Through discussion, arrive at a group consensus on five skills or items of knowledge that are critical for building understanding of the rock cycle.

5. Enter the final consensus knowledge and skills into the online Unit Planner. Have one member of each group enter the information into the group's planner.

6. Have the whole group discuss typical misunderstandings.

Discuss misunderstandings that students might have about the rock cycle. Aggregate them in one large list.

7. Enter the misunderstandings into the online Unit Planner.

Have one member of each group enter the information into the group's planner.

8. Congratulate the teams for completing the entire Stage 1 of a unit on the rock cycle.

Notes

During this part of the design process, accept all responses for potential misunderstandings about the rock cycle. Later, in the week, teachers will be introduced to notion of "misconceptions" in science, a unique category of student misunderstandings.

HANDOUT 24**Knowledge and Skills for The Rock Cycle**

List the key knowledge and skills that students will need in order to answer the essential questions and attain the understandings that have been identified for the Rock Cycle unit.

1.

2.

3.

4.

5.

Group Members _____

Date _____

HANDOUT 25

Potential Misunderstandings for The Rock Cycle

List the potential preconceptions and misconceptions that students may have before they begin to study the Rock Cycle.

- 1.
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.
- 8.

HANDOUT 26

Reflection Day 2 Morning

Name: _____ Date: _____

What difficulties did you encounter while developing understandings for the Rock Cycle Unit?

Argue the case that “What is a rock” is an essential question. Now, argue the case that “What is a rock” is **not** an essential question.

ACTIVITY 10

Introducing Assessment

Description

This activity introduces teachers to the role of assessment in the UBD/ESBD approach. They learn where assessment fits in the “backward design” process and how using a “suite” of assessments throughout a unit of study will give them a better ability to measure the true level of student understanding. The activity clarifies the different purposes of “formative” and “summative” assessment and explains how to link assessment to the six facets of understanding. The activity introduces six design filters to assess the adequacy of the suite of assessments for a unit. It introduces the concepts of false negative and false positive as twin “evils” to be avoided in any assessment. It concludes with an example of an assessment that fails to meet some of the design filter criteria.

In Activities 11 and 12 that follow, teachers create an authentic performance assessment and an accompanying rubric. Activity 10 “sets the scene” by discussing some of the general issues in assessment.

Goals

Completing this activity will help teachers to:

- Recognize the importance and value of designing assessment before designing instruction
- Begin to understand the criteria by which assessments can be evaluated
- Design better assessments themselves
- Understand the specific value of authentic performance assessments

Materials

- ☐ *Stage 2: Assessment* PowerPoint presentation
- ☐ *ESBD Six Design Filters for Assessment* Handout 27

Approximate Time

30 minutes

Procedure

1. Display the Stage 2: Assessment PowerPoint presentation.

Use the Powerpoint presentation to introduce the key ideas of Stage 2 of the UBD/ESBD approach.
(ppt slide 1)



2. Introduce the idea of beginning to think of yourself as an assessor.

Grant Wiggins is fond of telling teachers: “Think like an assessor.” What he means is don’t think like an activity designer; think in terms of how you will know when students have learned the stuff. Think about your learning goals in terms of how you will measure the degree to which students have achieved them. For most teachers this is an unnatural way to think and behave. What is natural is to design the activities and then think about how to test or assess. “Backward design” insists that teachers reverse this sequence and think about assessment as soon as they

ACTIVITY 10 Introducing Assessment - Page 2

have the goal in place. In other words, they make it Stage 2 of the design process. ESDB encourages teachers to change their understanding of teaching to include a larger role for assessments.

(ppt slide 2)

3. Discuss the importance of assessment.

In ESDB and in UBD, assessment is viewed as an ongoing process. Assessment helps the teacher and the student see how things are going. Both students and teachers use assessment to keep on track and to make “course corrections” when needed. Assessment that occurs only *after* all the learning activities cannot be used to *guide* those learning activities. (Teachers can use it to revise for *next* year, but it is little help for *this* year.) Assessment that is used to inform and guide learning is called “formative assessment.” The kind of assessment that most students and teachers are used to, which occurs at the end of learning, is called “summative assessment.” It has a place as “evidence for learning,” and should not be neglected. In UBD and ESDB we argue that the summative assessment should ask students to demonstrate deep and enduring understanding. At least one of the assessments used in summative assessment should be a performance assessment, preferably an authentic performance assessment. This is discussed more in the following activity.

(ppt slide 3)

4. Explain the role of the six facets in designing assessments.

If we are aiming for deep and enduring understanding, then the assessments should demand that students demonstrate the six facets of understanding. The rest of the institute will help teachers design such assessments. As will be discussed more in later sessions, in science we predominantly ask students to *explain* and *apply*. The challenge for ESDB teachers is to broaden assessments to include more of the remaining 4 facets.

(ppt slides 4 and 5)

5. Introduce the six design filters for assessment.

The suite of assessments that we use for any ESDB unit should collectively meet these 6 criteria.

- **Valid.** This simply means that the assessment provides evidence that lets us make inferences about student understanding. Does it measure what it says it measures? Is it free of bias?
- **Reliable.** An assessment is reliable if it produces consistent results over time and with different student populations.
- **Sufficient.** Assessments are sufficient if they provide enough evidence to “convict” students of understanding beyond a reasonable doubt. A single quiz is seldom sufficient, nor is a single end-of-unit test. Especially when teaching for understanding, we need many samples of student work, including oral, written, performance-based, and informal. If we really want to measure understanding we will use a *suite* of assessments so that we are really sure they understood.

ACTIVITY 10 Introducing Assessment - Page 3

- **Authentic.** Assessments are authentic if they are set in a meaningful context and involve a real or “simulated real” audience. There is more about authentic assessments in the next activity. The point to make here is that if we are aiming for deep and enduring understanding, authentic assessments will help us get there. Authentic assessments have two major functions in teaching: (1) they demand that students demonstrate understanding, and (2) they motivate students to acquire the knowledge and skills that can lead to real understanding.
- **Feasible.** An assessment must be feasible. This is why the audience is often “simulated” rather than the real audience.
- **Student-friendly.** The assessment should make sense to students and be engaging.
(ppt slide 6)

6. Explain the two key questions in assessment.

This slide introduces a central question in all of assessment—confidence in the results. Good assessments avoid *false negatives* and *false positives*. They avoid concluding that a student does not understand when in fact they do. They avoid concluding that a student does understand when in fact they do not. It is precisely in order to avoid these twin mistakes that we urge using a suite of assessments, assessing for all the facets of understanding, and using an authentic performance assessment.

7. Test an example from baseball against the six design filters for assessment

The presentation concludes with a proposed assessment drawn from baseball. By applying the 6 design criteria we are able to characterize the assessment as valid but not reliable nor sufficient even though it is authentic, feasible, and friendly. The example is meant to show that you really need all six criteria in order to have a good assessment. Experience in previous workshop settings has shown that people may be reluctant to admit that this assessment is valid. However, it is valid because it does measure what it says it measures—batting performance. It is not reliable, however, because you would get quite different results when you applied the assessment in repeated trials. What you need to do, and which baseball does, is look at average batting performance over repeated times at bat. This allows you to have confidence in the assessment results and avoid false positives and false negatives.

(ppt slides 8, 9, 10)

8. Take questions and introduce the next activity.

Remind participants that to effectively assess for understanding, you need a suite of assessments. An important and powerful part of that suite is an authentic performance assessment. In Activity 11 we will discuss the characteristics of an authentic performance assessment and learn how to design one using a design template.

HANDOUT 27

ESBD Six Design Filters for Assessment

We use six design filters, or criteria, to determine the adequacy of the assessments created for an ESBD unit. The first four criteria apply to each and every assessment; the fifth criterion applies only to the performance assessment; the sixth criterion applies to the suite of assessments taken together.

Each *individual* assessment should be:

- ✓ Valid
- ✓ Reliable
- ✓ Feasible
- ✓ Student-friendly

The *performance* assessment should also be: ✓ Authentic

Taken together, the *suite* of assessments should be:

- ✓ Sufficient

to “convict” the student of understanding “beyond a reasonable doubt.”

ACTIVITY 11

Designing Performance Assessments

Description

In this activity participants are presented with the major characteristics of authentic assessment, along with an explanation of how authentic assessments relate to performance assessments. Then they are introduced to a unit design tool, the GRASPS template. Finally, participants practice using GRASPS to design a performance assessment to accompany their rock cycle unit.

Goals

Completing this activity will help teachers to:

- Understand that performance assessments require students to demonstrate understanding
- Recognize that performance assessments are not necessarily authentic, but that ESBD strongly encourages the use of authentic assessments
- Design an authentic performance assessment

Materials

- ☐ *GRASPS Template Example* Handout 28
- ☐ *Authentic Performance Assessment Sample Vignette* Handout 28A
- ☐ *GRASPS Template* Handout 29
- ☐ *Performance Assessments* PowerPoint presentation

Approximate Time

60 minutes

Procedure



1. Display the Performance Assessments PowerPoint presentation.

Begin with slide 1.
(ppt slide 1)

2. Introduce the goals of the activity.

Remind participants that their unit's culminating assessment should measure deep and enduring understanding in a manner that "convicts" students of understanding. Emphasize that the culminating assessment is critical because it serves as the destination point that drives the unit. With the UBD/ESBD approach, students are aware that the purpose of their activities is to help them build the understandings necessary for the performance assessment.

(ppt slide 2)

ACTIVITY 11 Designing Performance Assessments - Page 2

3. Define authentic assessment and present some of its characteristics.

Point out that the defining feature of an authentic assessment is that it utilizes a real life task, rather than a decontextualized, school-based task.

(ppt slide 3 to ppt slide 12)

4. Explain the difference between authentic assessment and performance assessment.

Say something like:

Authentic assessment and performance assessment are two terms that can easily be confused. Authentic assessments are a type of performance assessment in which students demonstrate their understanding in a real life task. UBD (and ESBD) strongly encourage the use of an authentic assessment, but do not require it. In science, we often ask students to demonstrate their understanding in ways that are not necessarily authentic. For example, we might ask students to create a scale model of the universe or engage in a lab practical. However, to the degree that it is possible, UBD (and ESBD) promote the embedding of performance assessments within meaningful contexts. These contexts may be playful and imaginary. Recent research about how people learn indicates that achievement is enhanced when learning is situated within meaningful contexts.

(ppt slide 13)

5. Present an example unit understanding and an expected outcome that stems from it.

(ppt slide 14 to ppt slide 16)

6. Introduce the GRASPS template as a tool for designing authentic performance assessments.

Refer to Handout 28. Explain the parts of the GRASPS template by walking participants through a sample performance assessment aligned to the understanding presented on slide 15. Explain that the wording in the GRASPS template is written to the student.

(ppt slide 17 to ppt slide 23)

7. Discuss how GRASPS is a tool that assists teachers with writing an authentic performance task vignette.

Refer participants to Handout 28A for an example performance assessment vignette based on the Mt. Shasta example. Suggest that one way teachers might implement this type of assessment is to consider assigning different groups of students to different volcanoes (i.e. Mauna Loa, Mt. Rainier, Lassen Peak, etc.).

(ppt slide 24)



ACTIVITY 11 Designing Performance Assessments - Page 3

8. Use the GRASPS template to design authentic performance assessments for the rock cycle unit.

(Now that Stage 1 of the rock cycle unit is complete, it is a good time to place teachers into new working groups.) Explain that one of the expectations of the UBD/ESBD approach is that, whenever possible, an authentic performance assessment culminate each unit. Have participants work in small groups to design one for the rock cycle unit. They will not have time to write an actual vignette, but should be able to complete the GRASPS template. Have them record their ideas onto Handout 29. Remind teachers that as they think of a creative task, they should discuss the six design filters (Handout 27) to ensure that false negatives and false positives do not result from the task.

9. Have small groups report to the larger group.

Ask each group to chose a spokesperson to share the key elements of their performance assessment that they have recorded onto

10. Collect one GRASPS handout from each group, photocopy, and return a complete set to the participants.

Notes

This is the point in the unit design process at which the groups' unit plans will begin to diverge. All groups are working from the same enduring understandings, essential questions, and lists of knowledge and skill. However, there are many different kinds of performance assessments that can demonstrate deep understanding. Some teachers may design tasks in which students perform plays, argue court cases, or even peer teach younger students.

It may also be helpful to refer teachers to Chapter 7, *"Thinking Like an Assessor"*, of *Understanding by Design*. On pages 158 to 160, Wiggins and McTighe provide several examples of performance task vignettes that teachers may find useful as they try to come up with creative ideas for the rock cycle unit.

HANDOUT 28**GRASPS Template Example****Unit Title: Volcanic Eruptions**

Use this template to develop the vignette you will write to describe the authentic performance assessment to your students.

Goal**What is your goal?**

To reduce the loss of life and property damage by accurately predicting when, and to what extent, a volcanic eruption might affect Mt. Shasta.

Role**What is your role?**

You are an urban planner.

Audience**Who is your audience?**

Present your plan to the city council.

Situation**What is the situation?**

You have been asked to develop and present a risk assessment and mitigation plan for the city of Mt. Shasta.

Product**What should you produce?**

Prepare a PowerPoint presentation that includes a map and other supporting visuals. Generate slide pages for the audience.

Standards**What are the standards for your product?**

Your presentation should:

- inform the city council by telling the geologic story of Mt. Shasta
- include a research-based prediction of when the next eruption might occur.
- contain a map of the areas most likely to be affected by an eruption along with other visuals that support the presentation.
- include an emergency response plan based on the predicted flow of the path of the lava.
- be clear, persuasive, and scientifically accurate.

HANDOUT 28A

Authentic Performance Assessment Sample Vignette

Performance Task for Volcanic Eruptions Unit

You are an urban planner with the city of Mt. Shasta in California. You have been asked to develop and present a risk assessment and mitigation plan in the event that Mt. Shasta erupts. You hope to reduce the loss of life and property damage by accurately predicting when, and to what extent, a volcanic eruption might affect Mt. Shasta. You will need to prepare a plan that you present to the city council. Present your plan in the form of a PowerPoint presentation. Be sure to inform the city council with critical background information by telling the geologic story of Mt. Shasta. Include a research-based prediction of when the next eruption might occur. Prepare a map that shows the areas most likely to be affected by an eruption. Describe your emergency response plan based on the predicted flow of the path of the lava. In addition to maps, it is fine to use additional visuals as needed, as long as they support the presentation. Your presentation should be clear, persuasive, and scientifically accurate.

HANDOUT 29

GRASPS Template

Unit Title:

Use this template to develop the vignette you will write to describe the authentic performance assessment to your students.

Goal

What is your goal?

Role

What is your role?

Audience

Who is your audience?

Situation

What is the situation?

Product

What should you produce?

Standards

What are the standards for your product?

ACTIVITY 12

Creating Rubrics

Description

In this activity, participants are introduced to rubrics as a useful tools for evaluating performance assessments. They view examples of a criterion list and some rubrics. They learn to distinguish between a criterion list, a holistic rubric, and an analytic one. They find out that an analytic rubric specifies independent attributes to evaluate the task and includes levels of performance, as well as indicators for those performances. Last, participants use a blank template to create a rubric for their rock cycle performance assessment that they designed in Activity 11.

Goals

Completing this activity will help teachers to:

- Recognize the difference between a criterion list, a holistic rubric, and an analytic rubric
- Explain the features of an analytic rubric
- Design or modify an analytic rubric to evaluate a performance assessment

Materials

- ☐ *Rubrics* PowerPoint presentation
- ☐ *Criterion List for Science Lab Report* Handout 30
- ☐ *Holistic Rubric for Science Lab Report* Handout 30A
- ☐ *Analytic Rubric for Science Lab Report* Handout 30B
- ☐ *Volcanic Eruptions Rubric Construction* Handout 31
- ☐ *Assessment 1: Mystery Planet* Handout 31A
- ☐ *A Template for Rubric Construction* Handout 32

Approximate Time

60 minutes

Procedure



1. Display the Rubrics PowerPoint presentation.

Begin with slide 1. (*ppt slide 1*)

2. Introduce the goals of the activity.

Explain to participants that they'll be using a rubric to score their unit's culminating performance assessment. (*ppt slide 2*)

3. Remind participants that there are many ways to score assessment instruments.

Items can be marked as correct/incorrect, as with multiple choice and true/false questions or they can be evaluated based on adherence to standards. The scoring of a performance assessment usually relies on the second approach. Refer participants to Handout 30. A common tool that many teachers use when evaluating

ACTIVITY 12 Creating Rubrics - Page 2

student performances on various projects is the criterion list. It assigns point values to aspects of the project, frequently on a presence/absence basis. It is basically a checklist with point values listed for each scoring criteria. For example, when using a criterion list to evaluate a lab report, 5 points might be assigned for the inclusion of the research question, another 5 points for the hypothesis, 10 points for describing the experimental procedure, 20 points for the analysis of data, and 20 points for the conclusion section. The difficulty with using a criterion list is that it does not specify *levels* of performance or *indicators* of successful performance.

(ppt slide 3, ppt slide 4)

4. Explain that a rubric is a useful tool for evaluating performance assessments and that there are two main kinds: holistic and analytic.

Refer participants to Handouts 30A and 30B. A rubric can be thought of as an extension of the criterion list. However, a range of levels is possible for each aspect of the project and indicators (examples) of performance are described. Point out that the difference between a *holistic* and an *analytic* rubric is that the analytic one uses multiple scales so that specific attributes of the performance are evaluated separately. These might include Earth science content, scientific inquiry skills, presentation skills, and others. A holistic rubric is equivalent to one row of an analytic rubric.

(ppt slide 5)

5. Describe the key features of an analytic rubric.

Explain what is meant by specific attributes, levels of performance, and indicators of performance.

(ppt slide 6 to ppt slide 9)

6. Provide one or more examples of an analytic rubric and discuss the indicators.

Refer participants to Handouts 30 to 31A. In a large group format, discuss the indicators of performance. Point out that the goal of an analytic rubric is to clearly specify what is expected of students so that they can achieve at the highest levels. Deep understanding is the end goal. Because of this, the UBD/ESBD approach advocates setting high standards. Thus, the levels of performance in an analytic rubric do not strictly correlate with letter grades. For example, consider the 3rd level, Capable, of the Analytic Rubric for a Science Lab Report (Handout 30B). The Capable category is not really an average level of performance. Rather, it can be thought of as a minimum level of mastery that all students must meet. Do point out, that in a manner similar to criterion lists, the parts of an analytic rubric may be weighted differently.

(ppt slide 10, ppt slide 11)

7. Discuss strategies for developing rubrics.

In figure 8.3 on Pages 178 and 179 of *Understanding by Design*, Wiggins and McTighe offer a framework that can be used to generate indicators of understanding for the six facets. The indicators described in figure 8.3 (or adaptations of them)

ACTIVITY 12 Creating Rubrics-Page 3

can be applied to other attributes of rubrics. For example, refer participants to Handout 30B and point out how the indicators for Quality of the Research Question have been taken from the Explained column in the Six-Facet Rubric.

Another way to come up with ideas for the language of the indicators is to use an online rubric-generating tool, such as Rubistar at <http://rubistar.4teachers.org/index.php>. Briefly point out this resource to teachers, but do not spend a lot of time on it now. Tell them that they will have an opportunity to use tools like Rubistar in the second week of the summer institute when they develop a rubric for the performance assessment of their own ESBD unit.

Last, tell teachers that the first time that they use a performance assessment, they will only be guessing at what the student products might look like. Tell teachers that one of the best ways to generate performance indicators for a rubric is to derive them directly from student work. Pgs 181 and 182 of Understanding by Design lay out a six-step process for doing this.

8. Ask participants to return to their Rock Cycle groups and distribute a blank copy of *A Template for Rubric Construction Handout 32*.

Have participants begin by listing aspects of the performance assessment (accompanying their practice unit) that they would want to score. Then have groups fill-in across a row, at least one set of indicators that they might use to score that aspect of the performance assessment.

(ppt slide 12)

9. Have small groups report to the larger group.

Ask each group to choose a spokesperson to share the attributes of their performance that they choose for scoring along with one row of the analytic rubric.

10. Collect one rubric from each group, photocopy, and return a complete set to the participants.

Notes

Writing rubrics, especially coming up with independent attributes and meaningful descriptors is not an easy process. Before teachers try to design their own rubrics it may be useful, if time permits, to have them try to modify one first. The Mystery Planet Rubric is a rubric that can be improved upon. Consider having teachers discuss the indicators and/or revise them to strengthen the rubric.

As teachers look over the sample rubrics, they may notice that some indicators are the same, even for different levels of performance. For example, the indicators for levels 5, 4, and 3 for The Nature of the Hypothesis attribute on Handout 30B are identical. In this case, the designer chose to set as mastery the highest level of performance. That is OK. For some indicators, it simply does not make sense to describe “more” or “less” of a quality. The hypothesis cannot be more refutable or less refutable. This, in turn, can limit the number of levels that one might use for that attribute.

HANDOUT 30

Criterion List for Science Lab Report

5 pts	Research Question
5 pts	Hypothesis
10 pts	Experimental Procedure
20 pts	Analysis
20 pts	Conclusion
<hr/>	
60 pts	Total

Handout 30A

Holistic Rubric for Science Lab Report

5 Highly Proficient	4 Capable	3 Adequate	2 Limited	1 Inadequate
<p>The lab report contains the five required sections (i.e. research question, hypothesis, experimental procedure, analysis, conclusion). The research question is sophisticated. The hypothesis is refutable and directly relates to the research question. The experimental procedure is logical and can be replicated. Analyses are comprehensive and appropriately carried out. All conclusions are thorough, insightful, and fully supported by the analyses. The report thoughtfully conveys the ideas and all scientific information is accurate.</p>	<p>The lab report contains the five required sections (i.e. research question, hypothesis, experimental procedure, analysis, conclusion). The research question is revealing. The hypothesis is refutable and directly relates to the research question. The experimental procedure is logical and can be replicated. Meaningful analyses have been appropriately carried out. All conclusions are fully developed and supported by the analyses. The report clearly conveys the ideas and all scientific information is accurate.</p>	<p>The lab report contains the five required sections (i.e. research question, hypothesis, experimental procedure, analysis, conclusion). The research question is in-depth. The hypothesis is refutable and directly relates to the research question. The experimental procedure consists of steps that can mostly be replicated. Appropriate analyses have been carried out. All conclusions are fully supported by the analyses. The report systematically conveys the ideas but contains a few minor scientific inaccuracies.</p>	<p>A major section of the lab report is missing or some sections are incomplete (i.e. research question, hypothesis, experimental procedure, analysis, conclusion). The research question is somewhat developed. The hypothesis is refutable and somewhat relates to the research question. The experimental procedure is missing steps that make it difficult to replicate. Analyses have been carried out, but may not be appropriate or needed. Conclusions are not fully supported by the analyses. The report incompletely conveys the ideas and contains some serious scientific inaccuracies.</p>	<p>Two or more major sections of the lab report are missing or most sections are incomplete (i.e. research question, hypothesis, experimental procedure, analysis, conclusion). The research question is naive. The hypothesis is not refutable or does not directly relate to the research question. The experimental procedure is illogical and cannot be replicated. Limited analyses have been carried out, but may not be appropriate or needed. Conclusions are irrelevant and do not support the analyses. The report superficially conveys the ideas and most scientific information is inaccurate.</p>

HANDOUT 30B

Analytic Rubric for Science Lab Report

	5 Highly Proficient	4 Capable	3 Adequate	2 Limited	1 Inadequate
Completeness of the Report	All five required sections present	All five required sections present	All five required sections present	A major section missing or some sections incomplete	Two or more major sections missing or some sections incomplete
Quality of the Research Question	Sophisticated	Revealing	In-depth	Somewhat developed	Naive
The Nature of the Hypothesis	Refutable and relates to research question	Refutable and relates to research question	Refutable and relates to research question	Refutable and somewhat relates to research question/OR/Not refutable, but relates	Not refutable or does not relate to research question
The Experimental Procedure	Logical and replicable	Logical and replicable	Consists of steps that can mostly be replicated	Missing steps that make it difficult to replicate	Illogical and cannot be replicated
Analyses	Comprehensive and appropriately carried out	Meaningful and appropriately carried out	Appropriate and carried out	Carried out, but may not be appropriate or needed	Limited analyses that may not be appropriate or needed
Quality of Conclusions	Thorough, insightful, fully supported	Fully developed and supported	Fully supported	Not fully supported	Irrelevant; not supported
Expression of Ideas	Thoughtful	Clear	Systematic	Incomplete; fragmented	Superficial
Spelling and Grammar	No spelling or grammar mistakes	Limited spelling and grammar mistakes	Spelling and grammar mistakes do not interfere with readability	Spelling and grammar mistakes distract from readability	Spelling and grammar mistakes too numerous to count
Scientific Accuracy	Accurate	Accurate	Contains a few minor inaccuracies	Contains some serious inaccuracies	Mostly inaccurate

HANDOUT 31

Volcanic Eruptions Rubric Construction

Attributes	5 Highly Proficient	4 Capable	3 Adequate	2 Limited	1 Inadequate	Weight
Geologic story	Comprehensive story that is scientifically accurate	Revealing story that is scientifically accurate	Complete and scientifically accurate	Missing some content but scientifically accurate	Incomplete and scientifically inaccurate	
Eruption prediction supported by evidence	All evidence clearly supports prediction	All evidence clearly supports prediction	All evidence clearly supports prediction	Some evidence supports the prediction	Evidence does not support prediction	
Emergency Response Plan	Insightful	Thorough	Considered	Aware	Unaware	
Maps and Visuals	Support and are integral to the presentation	Fully support the presentation	Mostly support the presentation	Have limited value; connected only loosely to the presentation	Used decoratively	
Expression of Ideas	Thoughtful	Clear	Systematic	Incomplete; fragmented	Superficial	
Spelling and Grammar	No spelling or grammar mistakes	Limited spelling and grammar mistakes	Spelling and grammar mistakes do not interfere with readability	Spelling and grammar mistakes distract from readability	Spelling and too numerous to count	

HANDOUT 31A

Assessment 1: Mystery Planet

An application of the geological evidence of continental drift

Mystery Planet-An application of the geological evidence of plate tectonics.

Goal: Students will reconstruct a super continent from individual continents located on an imaginary planet, which has the same tectonic activity as Earth, using fossil, mineral, mountain evidence.

Situation: Students will be given geologic data on “maps” of the mystery continents. Using the evidence on the maps students will arrange the continents into a super continent. Students will also be expected to explain how the evidence supports their arrangement of the continents and how the evidence showing the previous arrangement of the continents supports the theory of plate tectonics.

Product: A completed map with the continents arranged according to the evidence given and an essay explaining how they used the evidence to solve the puzzle and how it relates to the theory of plate tectonics.

Rubric

	5	4	3	2	1
Grammar and Spelling	Few or no spelling and grammar mistakes	Spelling and grammar mistakes somewhat distracting to reader	Spelling and grammar mistakes distracting to reader	Spelling and grammar mistakes very distracting to reader	Spelling and grammar mistakes too numerous to mention
Accuracy of final map	Evidence transferred expertly and continents arranged correctly	Evidence transferred accurately and continents arranged correctly	Some evidence not transferred accurately but continents arranged adequately	Evidence not transferred accurately or continents arranged incorrectly	Evidence not transferred accurately and continents arranged incorrectly
Use of evidence to reconstruct the super continent	Evidence used expertly to reconstruct the super continent	All evidence used to reconstruct the super continent	Most evidence used to reconstruct the super continent	Some evidence used to reconstruct the super continent	Evidence not used to reconstruct the super continent
Explanation of evidence used to reconstruct super continent	Essay expertly explains evidence used to reconstruct super continent	Essay explains in an advanced manner evidence used to reconstruct the super continent	Essay explains in a basic manner evidence used to reconstruct the super continent.	Essay somewhat explains evidence used to reconstruct the super continent	Essay does not explain evidence used to reconstruct the super continent
Explanation of the theory of continental drift	Essay expertly explains the theory of continental drift	Essay explains in an advanced manner the theory of continental drift	Essay explains the theory of continental drift	Essay somewhat explains the theory of continental drift	Essay does not explain the theory of continental drift
Explanation of how RhSc is a model of Pangaea	Essay expertly explains how RhSc is a model of Pangaea	Essay explains in an advanced manner how RhSc is a model of Pangaea	Essay explains how RhSc is a model of Pangaea	Essay somewhat explains how RhSc is a model of Pangaea	Essay does not explain how RhSc is a model of Pangaea

A Template for Rubric Construction

Attributes	5 Highly Proficient	4 Capable	3 Adequate	2 Limited	1 Inadequate	Weight

HANDOUT 33

Reflection Day 2 Afternoon

Name: _____ Date: _____

Describe a situation in which you used a performance assessment during your teaching. How does it compare to one designed using the GRASPS model?

DAY 3

Introduction

Day 3 Overview

Today's activities focus on Stage 3 of the UBD/ESBD model. The first activity introduces WHERETO as a model for designing Stage 3 of an ESBD unit. The second activity emphasizes the importance of understanding student preconceptions before beginning to teach. The third and fourth activities introduce the use of visualizations in teaching.

Day 3 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Using WHERETO to Promote Understanding in Earth Science
10:00 -10:15	Break
10:15-11:45	Investigating Preconceptions and Misconceptions in Earth Science
11:45-12:00	Reflection
12:00-1:00	Lunch
1:00-2:00	Visualizations and Earth Science
2:00-2:15	Break
2:15-3:15	Visualizations and Earth Science (continued)
3:15-3:30	Reflection

ACTIVITY 13

Using WHERETO to Promote Understanding in Earth Science

Description

In this activity, the WHERETO model is presented as scaffolding for Stage 3 of UBD/ESBD. Teachers are introduced to a new method of organizing their traditional learning activities, while adding another dimension—Web and Internet resources. In this activity, participants discover the WHERETO model by experiencing activities representative of its seven parts. Teachers work through a series of hands-on activities and then discuss their sequencing. The WHERETO model is presented as a framework for organizing the curriculum that they will use to complete Stage 3 of their ESBD units. Visualizations and Web resources are integrated at several points to serve as examples of how to use them effectively in Stage 3.

Goals

Completing this activity will help teachers to:

- Understand the importance of letting students know **where** they are going and **why**.
- Be aware of a new way to structure their learning activities.
- Link Web and Internet resources logically with learning activities.

Materials

- ☐ A chalk or white board
- ☐ Chalk or pens
- ☐ Oranges or Styrofoam balls
- ☐ A bright light bulb and light bulb holder (200W works best)
- ☐ *Moon Phase Unit Preconception Survey Handout 34*
- ☐ *The WHERETO Model for Designing Stage 3 Handout 34A*

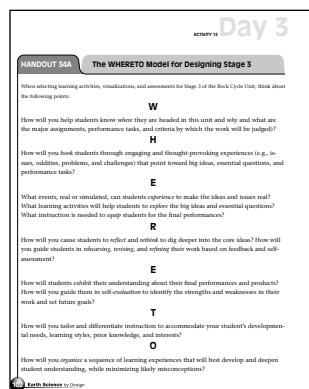
Approximate Time

75 minutes.

Procedure

1. Lead participants through a “W” activity for a Lunar Phases Unit (Where are we going and why?)

Draw a one-inch circle on the board. Place an “E” in the center of it (it represents Earth). Ask teachers to come to the board and draw a circle representing the moon at the size and position where they think it should be in relation to the Earth. Most teachers will draw the moon much closer to the one-inch Earth than it should be (30 Earth diameters = 30 in. or $8,000 \times 30 = 240,000$ miles) and will draw it larger than it should be ($1/4$ the size of Earth or $1/4$ ” in diameter at this scale. Draw the moon at correct scale size and distance on the board. Ask why we would want to study the moon considering how small and insignificant it seems to be? Why did the US spend billions of dollars landing on and exploring the moon (Apollo missions)? Hold a brief discussion on these issues.



2. Follow up with a preconception activity

Ask teachers where the moon is today and what phase it is in (look this up before the class...). When it is determined where the moon is in the sky and what it looks like, have teachers complete the *Moon Phase Unit Preconception Survey* Hand-out 34.

3. Demonstrate a Hook “H” activity.

Take teachers to the Teaching Resources section of the ESD Web site. Select the Space Science category. Choose the Moon journal activity and discuss how this activity can hook students and generate questions about the moon.

4. Lead participants through an “E” activity that enables them to Experience and Explore the unit’s ideas.

If it happens to be clear, and if the moon is visible during the day (moon in a waning phase), take your teachers outdoors and give them each an orange. Have teachers face south, hold the orange at arms length (stabbing a pencil into the orange to give them a handle makes viewing a little easier), and move the orange so that it covers the moon. Imagining that the teacher’s eyes are the “Earth” view, have them explain what they see (the orange has the same phase as the moon!). Have them draw the positional relationship of the sun, Earth, and moon that they observe.

Cloudy Day or Waxing Moon Option:

Perform a modeling activity with a standard light bulb, styrofoam balls, pencils, and again have teachers eyes act as the viewpoint of an observer on Earth. (Hint: to alleviate confusion, place the light bulb on one end of the classroom, not in the middle. That way all teachers will be seeing the same phase at the same time) Help teachers model the various phases of the moon starting with New, moving the styrofoam balls held at eye level counterclockwise through 1st quarter, then full, (styrofoam ball will be behind them at this point), then to 3rd quarter, back to New.

5. Demonstrate a Reflection “R” activity.

Take teachers to the Teaching Resources section of the ESD Web site. Select the Space Science category. Browse through the resources and suggest one as an appropriate reflection activity. (The current lunar phase, the Earth and Moon Viewer, or the WebQuest can each be effectively used as “R” activities).

6. Demonstrate an Evaluation “E” activity.

For an Evaluation “E” activity, repeat the Experience activity with one or two of the teachers demonstrating the primary phases of the Moon. Alternatively, show a standard type multiple-choice quiz. (Once again, refer participants to the Space Science section of the Teaching Resources at the ESD Web site for an example.)

ACTIVITY 13 Using WHERETO to Promote Understanding in Earth Science - Page 3

7. Carry out a post conception activity and have teachers discuss how the moon unit could be Tailored “T” to accommodate their students’ developmental needs and learning.

Ask teachers to re-examine their initial predictions in the *Preconception Survey* Handout 34. If possible, have them draw the correct phase and position of the moon in the sky on their diagrams for the day they made their predictions. They can later check themselves at the Naval Academy’s Virtual Reality Moon Phase site, accessible through the ESBD Teaching Resources. Then ask teachers to imagine themselves as their students. In what ways might they adapt this unit, if they were still having difficulty with moon phases? (If teachers do not bring this up, then suggest that they might want to have students go back and complete additional “E” & “R” activities). Furthermore, variations on units can exist as a means to tailor instruction to the differing needs of students. Instead of having a single unit plan, a teacher might develop multiple plans, varying Stage 2 and Stage 3.

8. Hold a large group discussion about the sequencing and Organization “O” of the activities.

At how many points did they have to confront their previously held beliefs about the phases of the moon? (They should answer “During each activity.”) Discuss why repetition might be an important tool in leading students towards a more correct view of difficult phenomena such as lunar phases. If any teachers in the workshop have taught moon phases before, ask how the WHERETO approach differs from the approach they used in the past.

9. Introduce the WHERETO model for teachers, outlining each step (See *WHERE-TO* Handout 34A).

Tell them to begin thinking of their Rock Cycle unit Stage 3 in terms of the WHERETO model. They will construct it during the next day of the workshop.

Notes

To shorten this activity, consider demonstrating the Step 4 Experience and Explore “E” activity in front of the group, instead of having every teacher do it.

In addition, be sensitive to teachers’ understandings about moon phases. Some teachers may be embarrassed by their own lack of knowledge. The goal of this activity is not to help teacher’s confront the limitations of their understanding, but rather for them to experience an abbreviated Stage 3 of an ESBD unit organized with the WHERETO model. Nonetheless, it is OK to mention that the process of designing an ESBD unit often causes teachers to rethink their understanding of the subject matter, which in turn, helps them to better prepare their students.

HANDOUT 34

Moon Phase Unit Preconception Survey

Based on your discussion of the moon's location and appearance in the sky at noon today, predict what the moon will look like, and where the moon will be in the sky one week from now. Draw a diagram of your prediction indicating the date, the time, the horizon (face the south), and indicate the phase and position of the moon in the sky.

Write a one or two sentence explanation of what causes the phases of the moon. Supply a diagram that illustrates your answer.

HANDOUT 34A

The WHERETO Model for Designing Stage 3

When selecting learning activities, visualizations, and assessments for Stage 3 of the Rock Cycle Unit, think about the following points:

W

How will you help students know *where* they are headed in this unit and *why* and what are the major assignments, performance tasks, and criteria by which the work will be judged)?

H

How will you *hook* students through engaging and thought-provoking experiences (e.g., issues, oddities, problems, and challenges) that point toward big ideas, essential questions, and performance tasks?

E

What events, real or simulated, can students *experience* to make the ideas and issues real? What learning activities will help students to *explore* the big ideas and essential questions? What instruction is needed to *equip* students for the final performances?

R

How will you cause students to *reflect* and *rethink* to dig deeper into the core ideas? How will you guide students in *rehearsing*, *revising*, and *refining* their work based on feedback and self-assessment?

E

How will students *exhibit* their understanding about their final performances and products? How will you guide them in *self-evaluation* to identify the strengths and weaknesses in their work and set future goals?

T

How will you *tailor* and differentiate instruction to accommodate your student's developmental needs, learning styles, prior knowledge, and interests?

O

How will you *organize* a sequence of learning experiences that will best develop and deepen student understanding, while minimizing likely misconceptions?

ACTIVITY 14

Investigating Preconceptions and Misconceptions in Earth Science

Description

In this activity, teachers view the “Private Universe” video and explore the notions of preconceptions and misconceptions in Earth science. This activity lays the groundwork to connect the analysis of student misconceptions to the WHERE TO model in a subsequent activity. The discussion of the phases of the Moon in the “Private Universe” video is used as a lead in to the modeling of effective W and H activities. Last, strategies for revealing misconceptions and building understanding are shared.

Goals

Completing this activity will help teachers to:

- Understand the nature of misconceptions in general
- Recognize the array of misconceptions in Earth science

Materials

- ☐ *Private Universe* video
- ☐ *Private Universe Viewing Guide* Handout 35
- ☐ The ESBD web site (www.esbd.org)
- ☐ *Strategies to Reveal Misconceptions and Build Understanding* Handout 36

Approximate Time

90 minutes

Procedure

- 1. Explain the difference between preconceptions and misconceptions and conduct a whole group discussion about ones that teachers have observed.**
Explain that students’ initial ideas about a concept are called their preconceptions. Sometimes these preconceptions are simply misunderstandings that arise from confusion about the scientific usage of everyday words or the meaning of similar terms (i.e. rotation versus revolution). At other times, these preconceptions reflect deep-seated ideas that are scientifically inaccurate and are referred to as misconceptions. Misconceptions can be persistent and enduring. Ask teachers to share any surprising student preconceptions or misconceptions that they have come across while engaged in Earth science lessons.
- 2. Describe the role of preconceptions/misconceptions in the UBD/ESBD approach.**
Point out that identifying potential student misconceptions is an important part of the Stage 1 UBD/ESBD unit design process. This in turn, drives the consideration of the selection of Stage 3 activities. Let teachers know that the ESBD approach strives to systematically shift students’ thinking from their strongly held misconceptions toward more enduring, scientifically accurate understandings. Teachers will need to appropriately select and sequence learning activities that enable students to confront, grapple with, and reconsider their understandings.

3. Introduce the “Private Universe” video.

Some teachers may have seen “Private Universe” at some point in their teaching careers. However, let them know that even if they have watched the program before, today they will be viewing it through the lens of unit design. Encourage teachers to not only think about the misconceptions that are discussed, but also to think about the kinds of activities and visualizations that might shift student thinking toward deeper understanding. Refer participants to the *Private Universe* Handout 35 for taking notes as they watch the program.

4. Show the “Private Universe” video.

It may be useful to stop the tape at various times to point out Heather’s misconceptions as they occur, especially if the teachers themselves have either limited knowledge or hold their own misconceptions in this subject area.

5. Hold a large group discussion about the questions and ideas on the Private Universe Viewing Guide.

Some of Heather’s misconceptions include light bouncing off of nothing in space and picturing Earth’s orbit as highly elliptical. Heather confuses Earth’s orbit with an analemma diagram she has seen in a textbook. Ask teachers to share initial ideas about activities or visualizations that they think might be helpful for Heather.

6. Share preconceptions and misconceptions in Earth science that have already been identified.

Take teachers to the Teaching Resources section of the ESD Web site. Select the Pedagogy category. Preview the lists found under the Misconceptions and Preconceptions links.

7. Discuss the nature of misconceptions and some strategies for revealing them and helping students build understanding.

Remind teachers that misconceptions are strongly held ideas that can be difficult to overcome. Refer participants to *Strategies to Reveal Misconceptions and Build Understanding* Handout 36 and discuss these strategies with them. Remind teachers that even after teaching, some misconceptions may endure. They should not become discouraged, but should use any information they gain from the students to help them to revise their units for the next time they teach the topic.

8. Conclude the activity.

Ask teachers to share any insights they have gained about misconceptions or any questions involving misconceptions that today’s activity brought up for them. Inform teachers that the topic of student misconceptions will be revisited through out the summer institute and again during the fall and spring follow up conferences.

Notes

Preview the “Private Universe” video before showing it to teachers. When first introduced to this topic, teachers may find it difficult to distinguish between preconceptions and misconceptions. In general, preconceptions are ideas that can be corrected through ordinary educational interventions. For example, a student thinks that the North Pole is on a land mass and then later learns that it is on an ice sheet. Misconceptions, on the other hand, are often abstract ideas that involve student juggling of multiple concepts in multiple dimensions. For example, a student may believe that the seasons are caused by Earth being farther or closer to the sun. To overcome this misconception, a student must put together the following ideas: the motion of Earth around the sun, the tilt of Earth’s axis, heating effects, temperature changes, length of time the sun is in the sky, and possibly others. Making sense of all these ideas is challenging and requires strategies that enable students to confront their own understanding.

The Private Universe video can be obtained from the Science Media Group, Harvard-Smithsonian Center for Astrophysics, 60 Garden St., Cambridge, MA 02138.
Email: private.universe@cfa.harvard.edu

Private Universe Viewing Guide

1. What are the two major misconceptions discussed in this video?
2. What are two of the other misconceptions that Heather uses in her discussion of the two major ones?
3. What activities or visualizations might you use with Heather to help her overcome her misconceptions?

HANDOUT 36

Strategies to Reveal Misconceptions and Build Understanding

- Conduct a written Preconception Survey at the beginning of a unit
- Give students many opportunities to reveal their thinking and their emerging understandings.
- Create a classroom climate where it is OK to share one's misunderstandings and partial understandings.
- Positively reinforce students when they reveal their struggle to understand.
- Acknowledge to students that building understanding takes time.
- Encourage students to monitor their own understanding through self-checks, reflections, and ungraded quizzes.
- Use assessment techniques that make student thinking visible, such as drawing and concept mapping.
- Probe student responses to get at their deep, rather than, surface understandings.
- Make frequent checks for understanding to monitor student understanding.
- Use activities that force students to confront their misconceptions and rethink their understanding.

HANDOUT 37

Reflection Day 3 Morning

Name: _____ Date: _____

What insights have you had about the role of misconceptions in teaching and learning?

ACTIVITY 15

Visualizations and Earth Science

Description

In this activity, teachers are shown examples of scientific visualizations and are introduced to a working definition of a scientific visualization. They are led on a tour of NASA's Earth Observatory and Scientific Visualization Studio. They discuss the value of using visualizations to support their Earth science teaching. They collaborate in teams to evaluate the potential of using particular visualizations to address a set of understandings and Big Ideas in Earth science. They use guidelines for evaluating the visualizations as they critically examine each of them. Teachers identify one visualization that their group would use for uncovering the Big Idea and describe the part of WHERETO in which they would likely use that visualization. They also identify one visualization that their group would not use for uncovering the Big Idea. They share their rationales for their selections as well as any issues or insights raised during the group discussions.

Goals

Completing this activity will help teachers to:

- Understand what is meant by scientific visualization
- Know where to find scientific visualizations
- Recognize the power of scientific visualizations to support learning
- Use scientific visualizations to teach earth science concepts
- Select appropriate scientific visualizations for incorporation into an ESBD unit by evaluating their suitability

Materials

- ☐ *Visualizations and Earth Science* PowerPoint
- ☐ *Evaluating Visualizations* Handout 38
- ☐ *Evaluating Visualizations: An Example* Handout 39
- ☐ *Visualization Sets* Handouts 40, 41, 42, 43, and 44
- ☐ Internet-connected computers and a computer projector for accessing the ESBD website and the Teaching Resources/Visualizations Sets section

Approximate Time

2 hours

Procedure

1. Display the *Visualizations and Earth Science* PowerPoint presentation. Begin with slide 1. (*ppt slide 1*)
2. Inform participants of the session goals. Explain that one of the major goals of the ESBD program is for teachers to use scientific visualizations to build students' understanding of Earth System Science. (*ppt slide 2*)

ACTIVITY 15 Visualizations and Earth Science - Page 2

3. Demonstrate some scientific visualizations, pointing out the type of data used and the processes on Earth that can be studied with the data.

Say something like:

Earth scientists routinely use satellite data to create images, maps, animations, and other representations to help them better understand and visualize processes that affect and shape our planet. They monitor earthquakes, track storms, measure sea surface temperatures and atmospheric temperatures, analyzing both short-term and long-term changes occurring on Earth. (*ppt slide 3*)

By animating a decade's worth of sea surface temperature data, Earth scientists can pick out periodic fluctuations, such as El Nino and La Nina events. They can study the movement of ocean currents and predict weather patterns. (*ppt slide 4*)

In particular, processes that occur over long periods of time can be animated and analyzed to help students understand the dynamic nature of planet Earth.

As time permits, use as many of the remaining examples in the PowerPoint to continuing highlighting Earth processes that can be studied through scientific visualization.

4. Introduce teachers to the ESBD definition of a scientific visualization.

The representations that Earth scientists use, are often known as scientific visualizations. Offer the following definition of a scientific visualization as a working ESBD definition.

Scientific visualization — an image, photograph, map, graph, chart, drawing, illustration, animation, or simulation whose purpose is to promote understanding of a scientific concept or process.

Emphasize that the ESBD program primarily focuses on map and image-based representations. Most teachers already incorporate graphs, charts, and drawings into their science teaching.

5. Provide a brief tour of NASA's Earth Observatory and Scientific Visualization Studio Web sites.

Both sites are accessible through the "Remote Sensing" section of the Teaching resources area of the ESBD Website. In particular, point out the "Today's Image" and the "Experiments" portion of the Earth Observatory. The "Today's Image" features a different image each day accompanied by short report that indicates the kind of data collected, along with a description of what the image shows. In the "Experiments" portion go to the "Patterns of Change" activity. Here teachers can build paired animations from various datasets to compare variables such as changes in vegetation and changes in precipitation across a specific time frame. Scientific Visualization Studio has an entire collection devoted to hurricanes. Choose some interesting visualizations to share and highlight.

6. Hold a brief discussion centered on the question, “Why should we use scientific visualizations in teaching Earth science?”

Raise the following ideas if teachers do not bring them up themselves:

Computer visualizations are central to the practice of Earth scientists.

Computer visualizations are dynamic and engaging.

Computer visualizations enable Earth science processes to be viewed over space and time in ways not possible with other media.

Computer visualizations can promote deep and enduring understanding.

7. Showcase a few exemplary visualizations used by ESBD teachers in their units.

The ESBD website publishes units of teachers who have participated in past professional development programs. Briefly present the instructional context for the visualizations and emphasize how each helps to uncover an Earth science understanding.

8. Present an evaluation of a scientific visualization.

Say something like:

As you look for visualizations to incorporate into your ESBD unit, consider the questions listed on Handout 38, *Evaluating Visualizations*. Elaborate and explain the questions by guiding teachers through the evaluation of one or two related visualizations. Refer to the worked example for the Crustal Age of the World’s Oceans as needed.

9. Facilitate small groups of teachers as they explore visualizations on Internet-connected computers.

Provide teachers with a grouped set of visualizations, a set of understandings, and the guiding questions for discussion. Allow teachers to explore visualizations on computer. Ask teachers to evaluate the visualizations and select from these one they would use to help uncover the Big Idea and one they would not use to help uncover the Big Idea. Inform teachers that each group will be presenting to the larger group, their selected visualizations, the rationale for their selections, and any issues or insights raised during the discussion.

10. Have teachers report their small group findings back to the larger group.

HANDOUT 38

Evaluating Visualizations

When evaluating the effectiveness of a visualization, consider both its basic design and your intended instructional use. Use these questions to guide your evaluation:

Grade level:

For what grade level is this visualization appropriate?

Instructional role:

What big and subsidiary ideas in Earth science will this visualization help students understand? Where does it fit in the WHERETO outline?

Accuracy:

Is this visualization scientifically accurate? Which person or agency created this visualization? What is the underlying data, and how was it collected and processed to create this visualization?

Background knowledge:

What content knowledge is needed to understand this visualization? Are preparatory activities or scaffolding needed to use this visualization effectively? If so, how can these be provided to students?

Embedded conventions:

What visual conventions does this visualization use that students might not understand or that might lead to confusion?

- *Scale:* Is the scale clearly indicated? Is there any exaggeration of scale? For example, is the vertical dimension exaggerated with respect to the horizontal dimension?
- *Legend and labels:* Are they present, clear, and adequate?
- *Projection:* Are there aspects of the projection (such as distortion of area) that need to be explained?
- *Color:* Is it clear what the colors in the visualization represent? Are the colors misleading or confusing?
- *Time and date:* Is the time and date information provided adequate to understand the visualization?

Misconceptions:

Might this visualization inadvertently introduce misconceptions or misunderstandings? If so, how can you provide additional information to guard against this misunderstanding?

HANDOUT 39

Evaluating Visualizations: An Example

An Example:

When evaluating the effectiveness of a visualization, consider both its basic design and your intended instructional use. Use these questions to guide your evaluation:

Visualization Evaluated: *Crustal Age of the World's Oceans* (found in the ESBD web site Teaching Resources/Visualizations by Design/Geosphere)

Grade level:

For what grade level is this visualization appropriate?

Grade 6, 7, or 8

Instructional role:

What big and subsidiary ideas in Earth science will this visualization help students understand? Where does it fit in the WHERETO outline?

Possible concepts this visualization may help uncover include:

- The age of the ocean floor varies from place to place.
- There are general patterns in the distribution of the age of the ocean floor.
- The distribution of the age of the ocean floor provides compelling evidence that plates move relative to one another.
- Plates move at varying rates and in varying directions.

It could be used as a (H) hook to engage students and then revisited again during the (E) explore, explain stage as well as to (R) review and reinforce.

Accuracy:

Is this visualization scientifically accurate? Which person or agency created this visualization? What is the underlying data, and how was it collected and processed to create this visualization? It was produced by NOAA and appears to be scientifically accurate. The data comes from Scripps Institute of Oceanography.

Background knowledge:

What content knowledge is needed to understand this visualization? Are preparatory activities or scaffolding needed to use this visualization effectively? If so, how can these be provided to students?

The background content needed to understand this visualization depends upon what the user is expected to “read” from the image. At the introductory level, when used as a hook (H), users need to be able to distinguish landmasses from ocean floor. As they describe and discuss patterns, it would also be helpful to have general knowledge of the locations of continents and major oceans. At the more advanced level (E), if students are expected to gather evidence from the image to support the notion that plates move relative to one another, then they would need to have a prior understanding of plates and plate boundaries.

Embedded conventions:

What visual conventions does this visualization use that students might not understand or that might lead to confusion?

- *Scale:* Is the scale clearly indicated? Is there any exaggeration of scale? For example, is the vertical dimension exaggerated with respect to the horizontal dimension?

There is no distance scale, but latitude and longitude lines are appropriately displayed.

- *Legend and labels:* Are they present, clear, and adequate?

Students may need to be told that B.P. stands for before present.

- *Projection:* Are there aspects of the projection (such as distortion of area) that need to be explained?

Not really. This particular projection does not appear to produce extreme distortions of the land masses.

- *Color:* Is it clear what the colors in the visualization represent? Are the colors misleading or confusing?

The colors in the image are “false”. The ocean floor does not look like this. Students might need help understanding that the colors represent age and not elevation.

- *Time and date:* Is the time and date information provided adequate to understand the visualization?

Yes.

Misconceptions:

Might this visualization inadvertently introduce misconceptions or misunderstandings? If so, how can you provide additional information to guard against this misunderstanding?

Because the landmasses are gray and the ocean floor is vividly colored, the eye is often drawn first to the ocean floor. This makes it difficult for students to orient to the image. Call their attention specifically to the continental landmasses. Making sure students can locate North and South America, and perhaps Africa will help make the image less confusing.

HANDOUT 40**Visualization Sets**

In this activity you will collaborate with your colleagues to evaluate the potential of using particular visualizations to address a set of understandings and Big Ideas in Earth science. Use the guidelines for evaluating visualizations to critically examine each of the visualizations in a set. Assume that you are interested in uncovering the Big Idea provided. The understandings that have been listed are all related to the Big Idea. However, each visualization will not necessarily target all of the understandings. As you discuss these visualizations, feel free to add or revise understandings as needed.

After you have evaluated the visualizations, be prepared to share:

- a visualization that your group would use for uncovering the Big Idea and in what part of WHERETO you would likely use it
- a visualization that your group would not use for uncovering the Big Idea
- the rationale for your selections (e.g. why you would or would not use them)
- issues or insights raised during your discussions

HANDOUT 41

Visualization Set 1: Geosphere

Big Idea:**Big Idea 5, The Geosphere**

The movement of the Earth's lithospheric plates causes both slow changes in the Earth's surface (e.g., formation of mountains and ocean basins) and rapid ones (e.g., volcanic eruptions and earthquakes).

Understandings:

(You are encouraged to suggest additional understandings or revise the ones listed below.)

- The age of the ocean floor varies from place to place.
- There are general patterns in the distribution of the age of the ocean floor.
- New oceanic crust is formed where plates are pulling apart and that the presence of subduction zones means that oceanic crust does not get older than a few hundred million years.
- The dynamic motion of Earth's crust creates an ocean floor that varies in age in relation to its proximity to spreading ridges and subduction zones.
- The distribution of the age of the ocean floor provides compelling evidence that plates move relative to one another.
- As crustal plates move, their boundaries change so that new plates are created while others are recycled within the Earth.
- Convection currents in the mantle drive the motions of the plates.

Visualizations:

Refer to the Geosphere visualizations in the "Visualization Sets" section of Teaching Resources on the ESBD web site (www.esbd.org).

HANDOUT 42

Visualization Set 2: Hydrosphere

Big Idea:**Big Idea 12, The Hydrosphere**

Circulation patterns in the oceans are driven by density differences and by exchange of momentum with the atmosphere.

Understandings:

(You are encouraged to suggest additional understandings or revise the ones listed below.)

- At the poles fresh water is frozen out of warm, salty seawater making it more saline and dense.
- More saline, dense water sinks to the ocean bottom.
- Surface water from low latitudes flows towards the poles to replace sinking cold water.
- Water in the world's deep ocean is circulated.

Visualizations:

Refer to the Hydrosphere visualizations in the “Visualization Sets” section of Teaching Resources on the ESBD web site (www.esbd.org).

HANDOUT 43**Visualization Set 3: Atmosphere****Big Idea:****Big Idea 10, The Atmosphere**

The atmosphere exhibits long-term circulation patterns and short-term patterns known as weather—storms, hurricanes, and tornadoes.

Understandings:

(You are encouraged to suggest additional understandings or revise the ones listed below.)

- Atmospheric pressure is not the same everywhere on Earth.
- Like all fluids, air tends to flow away from regions of high pressure towards regions of low pressure. This flow of air is known as wind.
- Winds spiral around areas of low pressure; the motion is counterclockwise in the Northern hemisphere and clockwise in the Southern hemisphere.
- The direction and force of a wind depend on the size of the pressure difference, the distance between high and low pressure areas, and the Coriolis effect.
- As Earth rotates about its axis, moving bodies, like wind and water, appear to someone on Earth to be deflected to the right in the Northern Hemisphere and to the left in the Southern Hemisphere. This phenomenon is known as the Coriolis effect.
- Some places on Earth are more likely to experience particular severe weather phenomena like tornadoes, hurricanes, thunderstorms, and floods while others are not.

Visualizations:

Refer to the Atmosphere visualizations in the “Visualization Sets” section of Teaching Resources on the ESBD web site (www.esbd.org).

HANDOUT 44

Visualization Set 4: Space Science

Big Idea:**Big Idea 20, Space Science**

The relative positions and movements of the Earth, moon, and sun account for the seasons.

Understandings:

(You are encouraged to suggest additional understandings or revise the ones listed below.)

- Earth experiences seasons that change throughout the year.
- Seasons on Earth vary by location.
- Earth revolves around the sun.
- Earth's orbit, while elliptical, is nearly a perfect circle.
- Earth rotates on an axis that is tilted.
- Sunlight hits different latitudes at different angles at different times of year.

Visualizations:

Refer to the Space Science visualizations in the "Visualization Sets" section of Teaching Resources on the ESBD web site (www.esbd.org).

HANDOUT 45

Reflections Day 3 Afternoon

Name: _____ Date: _____

What insights have you gained about teaching with visualizations?

What is the main unanswered question that you leave the institute with today?

DAY 4

Introduction

Day 4 Overview

Today and tomorrow are devoted to developing Stage 3 of each group's rock cycle sample unit. Participants use the WHERE TO model to design Stage 3 activities for their rock cycle unit. In Part One they work in small groups, using the Internet and other resources to identify activities aligned with their Stage 1 and Stage 2 that will lead their students to deep and enduring understanding of the rock cycle. In Part Two they review the Stage 3 resources found by other groups and use them to improve their own units.

Day 4 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Applying WHERE TO to the Rock Cycle Unit—Part One
10:0-10:15	Break
10:15-11:45	Applying WHERE TO to the Rock Cycle Unit—Part One (continued)
11:45-12:00	Reflection
12:00-1:00	Lunch
1:00-2:00	Applying WHERE TO to the Rock Cycle Unit—Part Two
2:00-2:15	Break
2:15-3:15	Applying WHERE TO to the Rock Cycle Unit—Part Two (continued)
3:15-3:30	Reflection
Homework	Think about the ESBD unit you may want to develop during week two.

ACTIVITY 16

Applying WHERETO to the Rock Cycle Unit – Part One

Description

In this activity, participants develop Stage 3 of their rock cycle sample unit. Participants are reintroduced to the structure of the WHERETO model. Then, working in small groups, using the WHERETO model to scaffold their work, they search through existing instructional materials for appropriate activities and search the Internet for new visualizations and activities. Participants use their group's resources and expertise to produce a Stage 3 that is aligned to their Stage 1 and 2 work.

Goals

Completing this activity will help teachers to:

- Become accustomed to using the WHERETO model to construct Stage 3 of ESD units.
- Obtain and use new visualizations and Internet resources in their Stage 3 design.

Materials

- ☐ Computers connected to the Internet—at least one for each group—and one connected to the projection device
- ☐ The Earth Science by Design Web site
- ☐ *The WHERETO Model for Designing Stage 3 Handout 34A*

Approximate Time

165 minutes

Procedure

Introduction and Initial Search for Stage 3

1. Review the WHERETO model

Teachers are ready to proceed to Stage 3 of their rock cycle sample unit. Before they go into their small groups, review the rationale of the WHERETO model that was described yesterday and go over the steps in the WHERETO model as outlined on the handout. These are the questions they should be asking themselves as they sift through their own tried and true activities as well as new visualizations and Internet resources. Emphasize the fact that most teachers usually launch into the E phase rather than approach a unit with a W and an H activity but that they should try to find activities and resources for all parts of WHERETO. Remind teachers that administering their preconception survey is part of the W section of their Stage 3 plan. A place for the actual preconception survey is provided in Stage 2 of the Unit Planner.

2. Describe the procedure for designing Stage 3.

Explain that they will be working in their small groups on Stage 3 activities and resources that support their Stage 1 learning goals and their Stage 2 assessments. They will use the Internet to search for resources for each stage of WHERETO. As they find resources and activities they will enter them into Stage 3 of their group's unit planner, indicating which part of WHERETO each resource supports. Although the working groups can use multiple computers to search the Internet, they should be entering everything into only one unit planner for their group.

ACTIVITY 16 Applying WHERETO to the Rock Cycle Unit – Part One - Page 2

Remind them to use the Teaching Resources database of the ESBD web site as well as other Internet resources.

3. Facilitate Stage 3 design work for the rock cycle unit.

Ask teachers to return to their rock cycle groups. Give them the rest of the session to search for and compile a list of Stage 3 WHERETO activities and visualizations. As teachers are working in small groups, circulate from group to group, checking that participants are choosing resources aligned with the goals of Stage 2 and Stage 3. Do not expect that they will find more than one or two activities in each WHERETO category.

4. Lead a whole group discussion about the process of designing Stage 3 of an ESBD unit.

Notes

If teachers are unfamiliar with searching the Internet, it may be useful to take some time to teach effective searching strategies as part of this activity. Most teachers have little difficulty locating E activities (Experience and Explore). However, they tend to have struggle a bit, and may need help finding appropriate Hook and Reflection activities. Furthermore, many teachers may not have previously incorporated visualizations into their teaching. As teachers search the Internet, continually ask them how the resource they have found relates to one of their activities or assessments and how it moves students to a deeper understanding of the subject.

HANDOUT 46

Reflection Day 4 Morning

Name: _____ Date: _____

How did our work with visualizations yesterday influence your thinking as you searched for visualizations for your Stage 3 today?

What was your greatest challenge or struggle as you worked to apply WHERE TO to your rock

ACTIVITY 17

Applying WHERETO to the Rock Cycle Unit – Part Two

Description

In this activity, participants make use of the Stage 3 resources found by other groups to revise their own Stage 3 framework for the rock cycle.

Goals

Completing this activity will help teachers to:

- Gain further practice using the WHERETO model to construct Stage 3 of ESBD units.
- Obtain and use new visualizations and Internet resources in their Stage 3 design.
- Use the professional expertise of other teachers in the construction of an ESBD unit.

Materials

- ☐ Computers connected to the Internet—at least one for each group—and one connected to the projection device
- ☐ The Earth Science by Design website
- ☐ A printed copy of each group's rock cycle sample unit for each group

Approximate Time

120 minutes

Procedure

Continuation of Activity Search and Group Sharing – 120 minutes

1. Discuss progress on the Stage 3 designs of rock cycle units.

To begin the second session, review the morning's work. Ask participants which WHERETO category activities and visualizations they found easiest to locate? Which were the most difficult?

2. Describe a strategy for improving the Stage 3 designs.

Explain that they are going to have some time now to look at the Stage 3 activities and visualizations located by the other groups in order to see whether there are resources they would like to use. Remind them that they should not accept activities simply because they might be fun or interesting to students. Rather, each activity should help students build toward the ideas identified as Enduring Understandings, help students grow in their capacity to answer the Essential Questions, and help students gain the skills and knowledge they will need to do well on the performance assessment. Each activity in Stage 3 is a *building block* in the overall unified structure whose framework is defined by Stage 1 and Stage 2. Give a copy of each group's Rock Cycle sample unit to each group.

ACTIVITY 17 Applying WHERETO to the Rock Cycle Unit – Part Two - Page 2

- 3. Have participants return to their small groups to revise their Stage 3 designs.**
Send teachers into their working groups and allow them to review the units of the other groups, especially the Stage 3 work. Tell participants that they are free to revise their Stage 3, using the activities and visualizations they believe will be effective in achieving deep and enduring understanding of the rock cycle. Facilitators should circulate from group to group to help ensure that participants are choosing resources aligned with the goals of Stage 1 & Stage 2. Facilitators should listen to conversations in order to get a sense of what participants are struggling with and what they are discussing.

- 4. Lead a whole group discussion about the process of designing Stage 3 of an ESBD unit.**
Reconvene the entire group and ask for their thoughts and reactions to the process of formulating Stage 3 of an ESBD unit. What was challenging? What was surprising? Which parts of WHERETO were easiest to complete? Which were the most difficult? What have they learned about searching for visualizations and resources on the Internet?

- 5. Ask teachers to begin thinking about topics for the ESBD units they will create.**
Tell teachers that their homework for tonight is to think about possible ideas and topics for the units they want to create next week.

Notes

As time permits, at the very end of the session, let participants use the computer attached to the projection system to share their favorite visualization related to the rock cycle that they have come across while working on their units.

HANDOUT 47

Reflection Day 4 Afternoon

Name: _____ Date: _____

Reflect on your experience in designing Stage 3 using the WHERETO model. How is this different from the way you have designed lessons and units in the past?

Please share any insights that you gained today about teaching and learning.

DAY 5

Introduction

Day 5 Overview

Today concludes the teachers' work on the rock cycle sample unit. Participants are introduced to the ESBD Unit Construction Checklist and use it to check their sample unit. Today you may opt to review any aspects of the material covered earlier in the week. Some teachers especially may need a review of the work of Stage 2—performance assessments and rubrics. Today you will ask teachers to select two other teachers they think they would work with well as a partner. By Monday of next week you will create the pairings you think will be most productive. You should also be gathering information about which staff members you think may work well with which teachers because next week you will be assigning a staff mentor to each teacher.

Day 5 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Continue work on the rock cycle unit in small groups
10:0-10:15	Break
10:15-11:00	Continue work on the rock cycle unit in small groups
11:00-11:45	Using the <i>Unit Construction Checklist</i>
11:45-12:00	Reflection
12:00-1:00	Lunch
1:00-2:00	Whole group review and celebration of all the rock cycle units
2:00-2:15	Break
2:15-3:15	Sharing ideas for units
3:15-3:30	Reflection
Homework	Over the weekend, think about the ESBD unit you may want to develop during week two. Next week, bring any materials and resources you want to have on hand as you begin to design your own unit.

ACTIVITY 18

Continue Work on the Rock Cycle Unit in Small Groups

Description	Give teachers time to continue working on Stage 3 of their rock cycle sample unit.
Goals	<p>Completing this activity will help teachers to:</p> <ul style="list-style-type: none"> • Complete Stage 3 of their ESBD rock cycle unit. • Obtain and use new visualizations and Internet resources in their Stage 3 design.
Materials	<ul style="list-style-type: none"> <input type="checkbox"/> Computers connected to the Internet—at least one for each group—and one connected to the projection device <input type="checkbox"/> The Earth Science by Design website
Approximate Time	120 minutes
Procedure	<ol style="list-style-type: none"> 1. Conduct a whole-group discussion about the status of their ESBD rock cycle units. Ask members of the small working groups to discuss where they are in their unit design and to describe any problems, challenges, or issues they are facing. Explain that they will have about an hour to finish up their Stage 3 work. Remind them that Stage 3 should have at least one activity for each part of WHERE TO. A preconception survey should be referred to in the W section and included in the Stage 2 section of the Unit Planner. 2. Facilitate Stage 3 design work for the rock cycle unit. Ask teachers to return to their rock cycle groups. Give them the rest of the session to search for and compile a list of Stage 3 WHERE TO activities and visualizations. As teachers are working in small groups, circulate from group to group, checking that participants are choosing resources aligned with the goals of Stage 2 and Stage 3.
Notes	Facilitators should be helpful when they can, but also listen to issues that teachers are discussing. This informal observing time, may help give a sense of which teachers would work well together as partners and which staff mentors would work with which teachers.

ACTIVITY 19

Using the Unit Construction Checklist

Description

Teachers learn to use the *Unit Construction Checklist* to check a unit for alignment and completeness. They use the checklist to check the rock cycle sample unit they have designed and then share their findings in a whole group discussion.

Goals

Completing this activity will help teachers to:

- Check their ESBD rock cycle unit for completeness and alignment
- Determine work that remains to be done on their unit

Materials

- ☐ Internet access for each group to the ESBD online Unit Planner
- ☐ *Earth Science by Design Unit Construction Checklist* Handout 48 and overhead transparency
- ☐ Overhead transparency projector

Approximate Time

45 minutes

Procedure

1. Introduce the checklist (15 minutes)

Distribute a copy of the *Earth Science by Design Unit Construction Checklist* Handout 48 to each teacher. Project the transparency of the checklist on the overhead. Explain that the checklist is a quick way to review a unit to see whether all stages are complete and whether they are aligned with each other. In a few minutes they will use the checklist to review the rock cycle units they have created.

Go through the checklist point by point and discuss any items that need clarification. Ask for questions.

2. Use the checklist to review the sample units

Let rock cycle groups go to their work areas. Instruct the teachers to work in pairs and evaluate the unit they have designed in terms of each item on the checklist. They should check off each item they feel is adequately addressed in the unit and make some brief notes about what needs to be done to bring the unit into alignment with the remaining items.

3. Share the results of the review

Reconvene as a whole group. Give a spokesperson from each group a few minutes to discuss only the areas in which the checklist revealed that their unit needs further work. They should briefly indicate how they would revise the unit to achieve completeness and alignment.

ACTIVITY 19 Using the Unit Construction Checklist - Page 2

Notes

1. As teachers are working in small groups, staff should circulate from group to group to help and to make sure that participants are choosing resources aligned with the goals of Stage 1 and Stage 2.
2. Staff should be helpful where they can, but also listen to issues that teachers are discussing. Staff also may be able to use this informal observing time to get a sense of which teachers would work well together as partners and which staff mentors would work well with which teachers.

HANDOUT 48

Earth Science by Design Unit Construction Checklist

Stage 1 - Identify Desired Results

- ☐ Do the enduring understandings relate *directly* to the big ideas in Earth science?
- ☐ Are all of the essential questions “how” or “why” questions rather than factual “what” questions?
- ☐ Is each essential question linked *directly* to one of the enduring understandings?
- ☐ Is each item listed in “What Students will need to know and be able to do” a direct result of one of the essential questions?
- ☐ Do *all* of the essential questions lie at the heart of Earth science and reveal the richness and complexity of the topic?

Stage 2 - Determine Acceptable Evidence

- ☐ Does the unit performance assessment address *most* of the enduring understandings listed in Stage 1 instead of a subset?
- ☐ Does the performance assessment truly *convict* the student of understanding?
- ☐ Does the rubric adequately evaluate student *understanding*?
- ☐ Does the performance assessment allow the evaluation of the understanding of *each and every* student in a fair and accurate way?
- ☐ Does the performance assessment serve as a *motivator* for students to acquire the deep understanding the unit seeks?
- ☐ Does the unit performance assessment force students to employ the majority of the knowledge and skills students should be able to know or do in Stage 1?
- ☐ In addition to the performance assessment, does the unit include enough other assessments (quizzes, prompts or self-assessments) to reveal the degree to which students *have or have not* mastered the enduring understandings?
- ☐ Does the Preconception Survey reveal student misunderstandings?

HANDOUT 48 Earth Science by Design Unit Construction Checklist - Page 2

Stage 3 - Plan Learning Experiences, Instruction, and Resources

- ☐ Does the collection of events in Stage 3 help to build *deep* and *enduring* understanding?
- ☐ Does each section of Stage 3 use a WHERETO letter, listing visualizations and Internet resources in sequence with the learning activities they augment?
- ☐ Does Stage 3 begin with an activity, demonstration, or discussion that addresses *why* students are studying the unit, and with one that uncovers *what* their preconceptions are?
- ☐ Does the unit have an engaging *hook* to grab students' interest?
- ☐ Does each student learning experience in the E section (explore/explain/equip/experiment) relate directly to the knowledge, skills, and abilities that underlie one of the essential questions?
- ☐ Does the unit provide the learning experiences that will help students excel on the performance assessment?
- ☐ Does each Web resource add perspective or deepen a student's understanding of the concept it relates to?
- ☐ Is each Web resource appropriate for the part of WHERETO in which it is used?
- ☐ Does the R (reflect/rethink) section, provide an activity or visualization that allows students to both review and look at a major concept in a different and engaging way?
- ☐ Does step E (evaluate) contain quizzes or self-assessments that allow students to monitor their own knowledge and proficiency as they progress through the unit?
- ☐ Are the activities tailored to your students' developmental needs, learning styles, prior knowledge, and interests?
- ☐ Does the unit *organize* student learning experiences, instruction, and resources using the WHERETO model?

Summative Questions

1. What are the strengths of this unit?
2. How could this unit be improved?

HANDOUT 49

Reflection Day 5 Morning

Name: _____ Date: _____

What insights about your unit and about the ESBD unit design process did you have as you reviewed your rock cycle unit using the *Unit Construction Checklist*?

ACTIVITY 20

Whole-Group Review and Celebration of the Rock Cycle Sample Units

Description

This session is a sharing and a celebration of the hard work that teachers have done in creating their rock cycle units. Each group gets time to share some aspects of their units by displaying them on the computer projection device. At the end, participants share their thoughts about the value of the experience of designing a unit this way.

Goals

Completing this activity will help teachers to:

- Share aspects of their units that they find exciting
- Reflect on the experience of designing an ESD unit

Materials

☐ Internet-connected computer connected to a presentation display device

Approximate Time

60 minutes

Procedure

1. Congratulate the participants

Congratulate the teachers on having completed the work of the first week of the institute—beginning to internalize the ESD approach to Earth science teaching and designing their first Earth science unit using the online Unit Planner. Now they are going to share the parts of their units that they are most excited about and together we are going to celebrate the hard work they have done.

2. Share the units

Give each group about 10 minutes, or whatever time allows, to bring up its own unit on the large display screen and discuss one or two resources or activities they are really pleased with and excited about using with students. Each group should explain how the resource helps students build deep and enduring understanding of the big ideas and answer the essential questions or if it is a Stage 2 activity helps provide evidence of that understanding. They should be encouraged to comment on which facets of understanding the activity taps into.

3. Review and reflect

Spend a few minutes at the end, reviewing what has been accomplished during the week, congratulating the teachers again, and soliciting comments on the experience. How has this been different from their previous approach to designing units and lessons?

ACTIVITY 21

Sharing of Ideas for Units

Description

In this session teachers take turns sharing their ideas for the unit they plan to design next year. Give each participant a few minutes to share their thoughts. Make sure everyone has a chance to share. Encourage participants to solicit ideas from their colleagues if they wish. Staff should take notes on the topics the teachers mention so that they can factor this information into their decisions about assigning mentors to teachers.

Goals

Completing this activity will help teachers to:

- Share ideas regarding the unit they want to create
- Gain ideas from fellow teachers

Materials

None

Approximate Time

60 minutes

Procedure

1. Introduce the session

Remind teachers that their task for next week is to design the unit they will teach during the following school year. Share with them the knowledge that experience has shown that teachers in previous institutes run by TERC do not emerge from the second week of the institute with complete and polished units. However, they will have a solid first draft and will know how to continue working on it after the institute. Remind them that the main goal of the Fall Teacher Conference is to polish their unit before beginning to teach it after that time. Explain that they now will take turns sharing whatever ideas they have for the units they want to create next week. Mention that if they want comments from their colleagues they should explicitly ask for them.

2. Sharing of topic ideas from each teacher

Give each teacher only about 2 minutes to describe a topic idea. They should briefly explain why they are thinking of choosing this topic and what is exciting about it for them.

Conclude the sharing with a reminder that over the weekend we hope you will rest and recuperate and also do more thinking about the unit you want to create so that you can hit the ground running on Monday. Gather and bring with you any materials and resources that you want to have handy as you begin your unit design.

3. Explain the role of teacher partners in the ESBD program

After everyone has had a chance to share a topic idea, explain the role of partnering in the ESBD program. Remind teachers that they have worked groups this

ACTIVITY 21 Sharing of Ideas for Units - Page 2

week, especially in designing their units. A lot of intellectual work benefits from having several heads working on it together, especially work that is new and hard. Therefore, although each teacher designs their own unit, they are going to have a partner to work with for the rest of the program. The program leaders will do the partner matching based on the preferences expressed by the teachers themselves and on other objective factors and on judgments about who would benefit from working with each other. The function of a partner is to act as a sounding board, a listener, and a source of constructive feedback. During the school year partners are encouraged to exchange visits to each other's classrooms during the time that the ESBD unit is being taught and to provide feedback to each other.

In today's reflection, each of you will be asked to list two others who you think you would work well with as a partner. The project team will take this into account in making partner assignments.

Notes

Some teachers may have very well-developed ideas while others may have only general ideas at this point. Try to make sure everyone realizes that it is OK at this point to not be sure of one's topic and to view this sharing as an opportunity to get feedback and ideas from colleagues. Reassure participants that the whole point of the Stage 1 work they will do early next week is to move toward clarity in defining the unit.

HANDOUT 50

Reflection Day 5 Afternoon

Name: _____ Date: _____

Write the names of two other participants that you think you would work well with as a partner in ESBD. If you wish, briefly explain why.

What is the main understanding that you struggled with this week?

What unanswered question or questions do you have from this week's activities?

Please comment on the process we have followed this week, including such things as the general pace, the atmosphere, the small group configurations, the group work, the whole group discussions etc. We welcome any ideas you want to share about what is working well and what might need improvement. Use the other side of the sheet, if necessary.

DAY 6

Introduction

Day 6 Overview

This week is devoted primarily to teachers working on the design of the Earth science units they will teach. The morning activities today introduce and analyze a sample unit: Journey to Planet Earth. In this activity, teachers gain familiarity with satellites, the instruments they carry and the kinds of data they collect. They explore satellite data and consider its application to the teaching of Earth science. Staff leaders assign partners and they begin work on their units.

In the afternoon, partners begin work on Stage 1 of their units. Mentors circulate and meet with partner groups.

Day 6 Schedule

8:30-8:45	Welcome and overview of the week
8:45-9:00	Review of a sample unit: Journey to Planet Earth
9:00-10:00	Satellite Search
10:00-10:15	Break
10:15-11:15	Satellite Search (continued)
11:15-11:45	Assignment of partners and initial work on units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners work on Stage 1 of their units
2:00-2:15	Break
2:15-3:15	Continue work on Stage 1 of units
3:15-3:30	Reflection

ACTIVITY 22

Review of a Sample Unit: Journey to Planet Earth

Description

In this activity, teachers preview *Journey to Planet Earth*, an Earth Science by Design Unit. They examine the structure and key elements of the unit. In Satellite Search, the next activity, they experience one of the activities from Stage 3 of *Journey to Planet Earth*.

Goals

Completing this activity will help teachers to:

- Think about the overall structure of an ESBD unit by examining a sample ESBD unit.
- Recognize how the performance assessment of Stage 2 can direct and guide the activities of Stage 3.

Materials

☐ *Journey to Planet Earth Unit Plan* Handout 51

Approximate Time

15 minutes

Procedure

1. **Distribute the *Journey to Planet Earth Unit Plan* and call attention to the Unit Description.**

Inform participants that the Unit Description presents an overview of the unit. Note that this unit also contains year-long overarching understandings that pertain to the entire course. Teachers who tend to think in “big picture” terms may find that they need to develop these types of larger goals in order to make sense of and frame their unit level goals. Such overarching understandings are not required in the unit plans, but may be useful for some teachers.

2. **Highlight the Unit Enduring Understandings and Essential Questions.**

Point out the correspondence between the two. Discuss the kid-friendly version of the essential questions. Remind teachers that the way in which they phrase essential questions for students may differ from the version they use for their own planning. However, the intent behind the reworded essential questions should remain the same.

3. **Ask teachers to look over the knowledge and skills section.**

Point out that as they learned in the previous week, these must align with the enduring understandings and essential questions. However, these goals are usually much more specific.

4. Remind teachers that identifying what it is that students may misunderstand is the last part of Stage 1 of a Unit Plan.

This part of the plan relies on teaching experience and can expand through conversations with other teachers as well as when individual teachers track their students misconceptions and misunderstandings through time.

5. Call attention to the performance assessment scenario for the unit and how teachers might introduce it.

Refer teachers to the W and H parts of Stage 3. It is this part of the plan that helps to provide direction and motivation for learning. Teachers should plan on posting essential questions in an area of their classrooms where they can easily be seen throughout the unit.

6. Present a visualization derived from satellite data and lay the context for pre-viewing it.

Ask teachers to imagine that they are middle school students on the first day of an Earth science unit. They have just been asked to look at the Earth from space as seen by the Apollo 17 and to write ten observations. They have also shared what they think they will be learning in Earth science. Next, show the Hologlobe movie (found on the High Resolution Images and Animations CD) that is listed as the Unit hook. Ask teachers to discuss their thoughts about this hook.

7. Ask teachers to look over the Stage 3 activities of the unit.

Remind them that as students experience these activities, their learning will be driven by their role in the performance assessment. As they prepare to depart on their journeys, the students will have a reason for wanting to get to know Planet Earth. Inform the teachers that they will be conducting one of the activities of this unit; Satellite Search. This activity will help them to use satellite data as a digital visual resource to support teaching and learning of big ideas in Earth science.

HANDOUT 51

Unit Plan—Journey to Planet Earth

Author: Carla McAuliffe, TERC

Stage 1: Identify Desired Results

Unit Description

Journey to Planet Earth is an introductory unit that presents Earth science as a voyage of discovery aimed at understanding the planet on which we live. This unit introduces the Earth system, and the major features of Earth's surface through remote sensing. Students acquire modeling and mapping skills as well as begin to build understanding of the methods of scientific inquiry.

Some understandings in Earth science overarch units as year-long goals. Four overarching understandings that pertain to this unit are as follows:

- The Earth is a system.
- Scientific discoveries often arise from a shift in perspective.
- Technology has led to increases in scientific knowledge and contributes to both better and worse living conditions.
- Scientific inquiry is a complex, iterative, and ongoing process.

Relationship to the Big Ideas in Earth Science

Directly relates to Big Ideas 4, 21, and 24 while beginning to uncover Big Idea 1 and 22.

Big Ideas 1, 21, 22, and 24 would come up repeatedly in a year-long Earth science course. Even Big Idea 4 would grow in depth throughout the year.

1. Earth can be conceived as an interacting set of processes and structures composed of the atmosphere, geosphere, hydrosphere, and biosphere.
4. The surface of the Earth has identifiable major features—land masses (continents), oceans, rivers, lakes, mountains, canyons, and glaciers
21. Earth scientists use representations and models, such as contour maps and satellite images to help them understand the Earth.
22. Scientists use quantitative, qualitative, experimental and non-experimental methods of scientific inquiry to understand the Earth.
24. Technological advances, such as seismic sounding and satellite remote sensing, advance Earth science knowledge.

Unit Enduring Understandings:

1. Earth is a dynamic system of interacting structures and features.
2. Remote sensing offers a new lens through which to study and monitor planet Earth. When we view the Earth from above the surface, we see the ways in which humans and Earth processes have altered it.
3. Maps, images, and models, both 2-D and 3-D, are representations that depend upon scale, location, projection, time, knowledge, tools, technology, and perspective.
4. Scientific observations and questions deepen our understanding of planet Earth.

Unit Essential Questions

1. What evidence demonstrates that Earth is a system?
2. What do satellite data reveal about the Earth system?
3. How do images and maps as well as 2-D and 3-D models help us understand the Earth as a system?
4. What are *scientific* questions and observations?
5. What questions can we ask and what observations can we make about the Earth system?

Possible rewording for students:

- What is this place called *Planet Earth*? (Which of its features play a critical role in the *Planet Earth* system? How are natural processes and humans affecting it?)
- What can we find out when we look at *Planet Earth* from space?
- How can we get to know *Planet Earth* from a *scientific* perspective?
- What *scientific* questions do you have about *Planet Earth*?

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

- Recognize that Earth is a system of interacting processes and structures that make up the atmosphere, geosphere, hydrosphere, and biosphere.
- Identify the major features of the Earth and their distribution such as land masses (continents), oceans, rivers, lakes, mountains, canyons, and glaciers.
- Describe that Earth is mostly water and that land is concentrated in the Northern Hemisphere.
- Picture map projections.
- Conceptualize scaled distances.
- Read and interpret a contour map.
- Recognize that a variety of satellites operate and that each specializes in collecting a specific type of data.

- Explain five applications of remote sensing to Earth science.
- Identify common features (i.e. roads, airports, rivers, irrigated fields, trees, etc.) visible in remote sensed images.
- Interpret remotely sensed images.
- Use Cartesian coordinates to locate features on a map or image.
- Use the data in a time-dependent process depicted in an image or series of images to predict future expected changes.
- Analyze images of changes occurring over time.
- Frame scientific questions and observations.

What do students typically misunderstand?

- Students frequently confuse latitude and longitude.
- Students may have difficulty conceptualizing scaled distances and areas.
- Students often get the notion that scientific inquiry takes place in discrete steps as in the “scientific method”.
- Students may misunderstand the two-sided nature of technology.

Stage 2: Determine Acceptable Evidence

G What is the Goal of the performance?

Your goal is to plan and conduct a scientific research expedition to a feature of *Planet Earth*.

R What Role does the student assume in the performance?

You are an explorer from another world who wants to know more about *Planet Earth*.

A What Audience does the student address?

Your target audience is the voting public on your home planet.

S What is the Situation for the performance?

Your home planet has recently discovered

Planet Earth. Teams from your planet will be taking voyages of discovery to it. Before you depart on your journey, you will need to get to know *Planet Earth*. What are its major features and characteristics? Where are its natural resources located? In preparation for your trip, and as a way to help you navigate this strange new world, carefully study maps and images of *Planet Earth*.

Along with your team members, design an expedition to a feature of *Planet Earth* that you find exciting. Imagine that you have the technology that lets you journey anywhere — even to places of extreme temperature and pressure. How will you travel there? What supplies will you take?

HANDOUT 51 Unit Plan—Journey to Planet Earth - Page 4

When you arrive at your destination, create a “profile” of your feature using 2-D and 3-D models and representations. You may choose to model a significant event that happened at that place in the past. Conduct research to find out how your feature has changed over time. Describe how remote sensing helps you better understand this feature. Gather and interpret at least three different images or maps of this feature. How does this feature interact with another? What is the relationship of humans to this feature? What questions does this feature raise for you? What else would you like to know about it?

Because your home planet wants a complete understanding of *Planet Earth*, you will need to negotiate features with other teams so that each Earth system (e.g. geosphere, atmosphere, biosphere, hydrosphere) is represented.

Some features that you might choose to visit include the following: a volcano, a fault, an ocean current, the edge of two fronts coming together, the Mid-Atlantic ridge, a crater, a mountain range, or a large area of natural habitat, such as a rain forest or a desert.

P What Product should be produced?

You would like to take more expeditions to your feature in the future. To do this, you will need to convince funders on your planet that the processes taking place at your location are critical to the *Planet Earth* system and are in need of scientific study.

On your planet, everyone has the opportunity to vote for which of these types of projects should be funded. After returning from your journey, you will need to present your findings to the voting public at an open meeting where anyone is able to pose a question.

Make your presentation as exciting as possible. After all, you are unlikely to receive the votes of funders if you do not capture their attention and hold their interest. Be sure to present a compelling argument for the significance of your feature to the *Planet Earth* system.

Share your discovery with others by preparing:

- A written report
- An oral presentation with accompanying visual display (Your team might create a poster, overheads or graphics and animations on computer.)
- A model of your feature

S What are the Standards for the product?

The written report should contain:

- a description of the feature (i.e. size, shape, color, etc.)
- detailed information about your feature (i.e. location, age, history, etc.)
- its relationship to other features on *Planet Earth*
- its relationship to humans
- the significance of this feature to *Planet Earth*
- at least five questions for further research

The model may be:

- physical or computer-based

Your presentation to the voting public will consist of:

- a brief summary of the findings from your journey
- a compelling argument for the significance of this feature to *Planet Earth*
- your plans for future research
- an oral report accompanied by supporting visuals

The report, the model, and the presentation will:

- contain all requested information
- convey information clearly and in an organized manner
- engage the audience
- use graphics to illustrate ideas and support arguments
- be visually appealing

Preconception Survey

Quizzes, Tests, and Academic Prompts

Apollo 17 Pre/PostConception Quiz Planet Earth Discovery Quiz or Where in the World is....? Remote Sensing Quiz

Other Evidence

Stage 3: Plan Learning Experiences, Instruction, and Resources

Use WHERETO as a guide to describe the learning experiences, instructional strategies, and resources you will use to help students address the essential questions of the unit and achieve deep understanding of the big ideas.

W & H (Where are they headed and Hooks)

- On the first day of class, have students write observations about the Apollo image of Earth from space. Compare this to an end of year writing sample of the same image. Set up the situation for the first unit's performance assessment. Tell students, "Imagine you are an alien from another world and have recently discovered this planet. You are told that it is called *Planet Earth*. Use your knowledge of the processes taking place on the planet and your understanding of it as a system to write ten detailed observations of *Planet Earth* in this view from space." http://nssdc.gsfc.nasa.gov/image/planetary/earth/apollo17_earth.jpg
- Have a discussion about what students expect they might be learning about *Planet Earth* this year. Continue to reveal the scenario of the performance assessment. "Your goal is to plan and conduct a scientific research expedition to a feature of *Planet Earth*." (Refer to Stage 2 for details.) Then share the overall year-long and unit essential questions with students.

HANDOUT 51 Unit Plan—Journey to Planet Earth - Page 6

- Generate student excitement and discussion about the study of *Planet Earth* by showing the HoloGlobe Project Movie at: http://svs.gsfc.nasa.gov/vis/a000000/a000100/a000155/hologlobe_v3.mpg

E (Experience, Explore, Equip)

- Understanding the *Planet Earth* System

Break students into “sphere” teams and have each one observe and analyze their sphere in the Hologlobe Movie at: http://svs.gsfc.nasa.gov/vis/a000000/a000100/a000155/hologlobe_v3.mpg

Present the basic features of the Earth system, such as the information found at: <http://www.cotf.edu/ete/ESS/ESSspheres.html> and <http://www.cotf.edu/ete/ESS/ESSmain.html>

- Previous visits to *Planet Earth*

Tell the class that early explorers from their planet visited *Planet Earth* in the past. Share what they saw and learned. (Use this context as an opportunity to incorporate historical information into the scenario about *Planet Earth*, including geologic history and technological discoveries.)

- Flattening *Planet Earth*

Have students peel apart paper models of *Planet Earth* and flatten them to demonstrate how map projections distort Planet Earth’s surface. Build the models shown here ahead of time:

<http://www.earthkam.ucsd.edu/public/educators/pdf/GeoMapsTennisBallGlobe.pdf>

- Interpreting Remotely Sensed Images

After completing the activities in *Watching Over Our Planet from Space* at http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/youthkit/intro_e.html students

- will be familiar with the basic concepts of “remote sensing” technology;
- will be able to recognize/interpret some features in satellite images;
- will be able to describe how remote sensing contributes to monitoring the environment.

For reference, refer them to the Fundamentals of Remote Sensing tutorial at: http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/chapter1/chapter1_1_e.html

Introduce NASA’s Earth Science Enterprise at:

<http://earthobservatory.nasa.gov/Library/ESE/> and describe the Earth Observing System.

Conduct *Satellite Search*

Conduct *Case Study: New Land along the Pearl River in Southern China* at http://serc.carleton.edu/eet/measure_sat/case_study.html

HANDOUT 51 Unit Plan—Journey to Planet Earth - Page 7

- Reading and Interpreting Contour Maps

Refer students to the online tutorials *Visualizing Topography* at: http://reynolds.asu.edu/topo_gallery/intro_title.htm

How are Landforms Represented on Flat Maps? at:

http://earthsci.terc.edu/content/investigations/es0307/es0307page01.cfm?chapter_no=investigation

- What are *Scientific* Questions?

Hold a class brainstorming of questions, followed by discussion.

- Locating Images of *Planet Earth*

Refer students to the following sites:

NASA's Earth Observatory

<http://earthobservatory.nasa.gov>

The Gateway to Astronaut Photography of the Earth

<http://eol.jsc.nasa.gov/>

ISS EarthKAM

<http://www.earthkam.ucsd.edu/>

Exploring Earth from Space Lithograph Set

<http://spacelink.nasa.gov/Instructional.Materials/NASA.Educational.Products/Exploring.Earth.From.Space/>

R (Reflect, Rethink)

- Have students write a reflective essay on one of the stories at *Earthshots:Satellite Images of Environmental Change* <http://edc.usgs.gov/earthshots/slow/tableofcontents>
- Review with *How are Earth's Sphere's Interacting?* at http://earthsci.terc.edu/content/investigations/es0103/es0103page01.cfm?chapter_no=investigation

E (Exhibit)

- Facilitate student presentations on their findings about *Planet Earth*. Direct the class to assume the role of the voting public on the home planet.

ACTIVITY 23

Satellite Search

Description

In this activity, teachers gain familiarity with satellites, the instruments they carry and the kinds of data they collect. They explore satellite data and consider its application to the teaching of Earth Science.

Goals

Completing this activity will help teachers to:

- Be able to describe some satellite instruments and the types of data they collect.
- Use satellite data as a digital visual resource to support teaching and learning of big ideas in Earth science.

Materials

- ☐ Internet Access
- ☐ *Satellite Search Sites* Handout 52
- ☐ *Satellite Search Question Sheet* Handout 53

Approximate Time

2 hours

Procedure

1. Inform participants of the session goals. Then present a visualization derived from satellite data.

Project a Sea Surface Temperature (SST) image or animation from NASA's Earth Observatory (<http://earthobservatory.nasa.gov/Observatory/Datasets/sst.avhrr.html>). By creating an animation for the year 1992, participants will be able to view an El Nino anomaly. Keep the legend hidden from participants and ask them to describe what they see. Ask them what they think the remotely sensed images show? Discuss how these images help Earth scientists monitor changes in weather and climate. Point out that although their students may have heard of El Nino, they likely have not interacted with satellite data showing the phenomenon developing over time. Remind them that in ESBD, satellite data and visualizations are used to bring perspective to the teaching of big ideas.

For a current list of relevant web sites, refer to the "Satellite Search" section of Teaching Resources on www.esbd.org.

2. From Data to Images: Remote Sensing and Satellites. Present and discuss key concepts of remote sensing and satellite imagery with participants.

Introduce general characteristics of satellites and remote sensing. Emphasize the following points:

- Remote sensing is way of gathering information about Earth without coming into direct contact with it (i.e. cameras on planes, shuttles, and satellites that fly over and take pictures of Earth are remote sensors).
- Satellites often carry more than one sensor.

ACTIVITY 23 Satellite Search - Page 2

- Sensors on satellites record energy that has been reflected or emitted by objects on Earth so that remotely sensed data are gathered either actively or passively.
- Sensors operate at various wavelengths of the electromagnetic spectrum.
- The measurement data collected by sensors are used to generate images that are made of pixels.
- Images produced from data gathered at different wavelengths (multi-spectral images) of the electromagnetic spectrum may be combined to help researchers discern specific features.

The following sites can be displayed as a backdrop for the discussion:

1) From NASA's Earth Observatory:

<http://earthobservatory.nasa.gov/Library/RemoteSensing/>

2) From the Canada Centre for Remote Sensing:

http://www.ccrs.nrcan.gc.ca/ccrs/learn/tutorials/fundam/chapter1/chapter1_1_e.html

3. Model small group activity expectations.

Describe the major characteristics of one Earth observing satellite instrument and the kind of data it collects. Showcase the Internet site for that instrument, highlighting the visualizations hosted on the site. For example, the sensors on the GOES satellites provide a rich dataset for looking at weather patterns (<http://www.oso.noaa.gov/goes/index.htm>).

4. Small group activity. Distribute *Satellite Search Question Sheet*.

Provide participants with list of URL's for Internet sites of five to ten satellites and/or missions. Ask each group of teachers to explore one of the sites. For their site, they will describe the major characteristics of the given satellite instrument and the type of data it collects or collected. Inform teachers that each group will be presenting to the larger group, information about their instrument and the kind of data it collects. They will also highlight the location of visualizations at the site and any other information that may be helpful when using this resource in the classroom. In addition to looking for images on the satellite's Web site, it may also be useful to search this list: Satellite data by satellite and sensor (instrument)_ <http://visibleearth.nasa.gov/Sensors/> Furthermore, you may want to encourage participants to search NASA's Earth Observatory to find representative images from their sensors (<http://earthobservatory.nasa.gov>).

5. Have small groups report back to the larger group.

Groups should present a tour of their Web site, sharing information about their instrument, the kind of data it collects, and the location of images or visualizations that might be used to support the teaching of Earth science concepts and big ideas.

HANDOUT 52

Satellite Search Sites

Satellite/Sensor

- TOPEX/Poseidon
<http://topex-www.jpl.nasa.gov/index.html>
- Landsat 7/ETM+ (Enhanced Thematic Mapper plus)
<http://landsat.gsfc.nasa.gov/>
- TRMM (Tropical Rainfall Measuring Mission)/Microwave Imager
<http://trmm.gsfc.nasa.gov/>
- QuickSCAT/SeaWinds Scatterometer
<http://windss.jpl.nasa.gov/missions/quikscat/quikindex.html>
- SeaStar/SeaWiFS
<http://seawifs.gsfc.nasa.gov/SEAWIFS.html>
- Terra/ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer)
<http://asterweb.jpl.nasa.gov>

For a current list of relevant web sites, refer to the “Satellite Search” section of Teaching Resources on www.esbd.org.

HANDOUT 53

Satellite Search Question Sheet

In this activity, you will describe the major characteristics of one Earth observing satellite instrument and the kind of data it collects. Your group will showcase the Internet site for this instrument, highlighting the visualizations and teaching resources hosted on this site.

Satellite Name: _____

Instrument Name: _____

How does the instrument gather data?

What kind of data does this instrument collect?

What are some applications of the satellite data? How do Earth scientists use them?

Where on the web site are the satellite data located?

What other resources does this site offer for teachers and students?

ACTIVITY 24

Assignment of Partners and Initial Work on Units

Description	Site leaders assign partners (two-person teams) and teams begin work on their units.
Goals	The goal of this activity is to assign teachers to the partner teams that the site leaders have determined. Following this, partners begin work on their units.
Materials	List of teachers in pairs, prepared in advance
Approximate Time	30 minutes
Procedure	<p>1. Assign teachers to their partner teams.</p> <p>Based on the information teachers had provided on Friday the site leader and staff have met and decided which teachers would work well together. Teachers are now informed of these decisions.</p> <p>Some factors to take into account in the creation of partner teams:</p> <ul style="list-style-type: none"> • <i>Grade level.</i> Teachers at the same grade level can often work better together because they share a common understanding of the curriculum and nature of students in this grade. • <i>Subject matter of their units.</i> Teachers working on similar or the same topics may be able to help each other more. • <i>Proximity.</i> Teachers in the same school or nearby schools can meet more often in person. • <i>Personality and working style.</i> During Week 1 you will have gotten a sense of which teachers may work more easily with each other. • <i>Complementary expertise.</i> It is often good to pair a teacher strong in subject matter content with someone who is weaker in content but may have other expertise to bring to the partnership. <p>2. Partners begin work on their units.</p> <p>Whether teachers use the online Unit Planner immediately or begin recording ideas on paper, they must begin with Stage 1 work. Staff mentors, though not yet assigned to particular teachers, circulate among teachers as they work and offer help and serve as sounding boards.</p>

HANDOUT 54

Reflection Day 6 Morning

Name: _____ Date: _____

What insights have you gained about satellite data? Which type(s) of data are you most likely to use in your teaching?

HANDOUT 55

Reflection Day 6 Afternoon

Name: _____ Date: _____

As you begin to plan your unit, what stage do you feel the most comfortable with? What stage do you feel the least comfortable with? Explain your feelings.

What was your greatest struggle as you worked on Stage 1 of your unit today?

DAY 7

Introduction

Day 7 Overview

This day is devoted primarily to teachers working on the design of Stage 1 of their Earth science units. Mid-morning features a video interview of experienced ESBD teachers sharing the challenges of ESBD design and teaching, followed by group discussion of the video. The day concludes with a review of Stage 1 of the units using the Unit Checklist. Throughout the day, staff mentors circulate and assist teachers with their unit design.

Day 7 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners continue work on Stage 1 of units
10:00-10:15	Break
10:15-11:00	Report from the field: video of ESBD teachers followed by discussion
11:00-11:45	Partners continue work on Stage 1 of units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners continue work on Stage 1 of units
2:00-2:15	Break
2:15-3:15	Check units for completeness of Stage 1
3:15-3:30	Reflection

ACTIVITY 25

Report from the Field Video and Discussion

Description

For this activity, teachers view and then discuss a video of experienced ESBD teachers relating their experiences implementing ESBD.

Goals

Completing this activity will help teachers to:

- Understand how implementing ESBD changed the thinking and behavior of two teachers
- Understand some of the challenges of implementing ESBD
- Understand how ESBD's new approach may affect students

Materials

- ☐ *Teacher Reflections: Reports from the Field* DVD
- ☐ *Video Discussion Questions: Part 1* Handout 56

Approximate Time

45 minutes

Procedure

The interview on the video was conducted in the summer of 2003 at TERC in connection with the ESBD Summer Institute. The interviewer is Valerie Crawford, of SRI International, the external evaluator for the ESBD project. The two teachers she interviewed are Anne Jones and Samantha Genier. Each of them was a participant in ESBD during the previous year. During the summer of 2003 they were serving as teacher consultants for the project. In the interview they share their reflections on their experience with the program during the past year.

- 1. Introduce the video by explaining when and where it was produced and who is in it.**
- 2. Hand out the *Video Discussion Questions: Part 1* Handout 56.**
Explain that teachers may use the discussion question sheet to take notes if they wish and that they will be discussing these questions after the video.
- 3. Show the video.**
Show the first two chapters of the reflections video. (*Teacher Profiles and Reports from the Field*)
- 4. Discuss the video as a whole group.**
Use the discussion questions on the handout, but, of course, additional questions may come up for discussion.

HANDOUT 56

Video Discussion Questions: Part 1

Reports From the Field video (about 9 minutes)

What did Sam and Anne indicate were the major changes in their classroom practice as a result of ESBD?

How did their students experience the new approach?

What new demands did ESBD make on students?

HANDOUT 57

Reflection Day 7 Morning

Name: _____ Date: _____

What insights did you gain from the video and discussion about the challenges of implementing ESBD?

ACTIVITY 26

Check Units for Completeness of Stage 1

Description

Working with their partners, teachers exchange printed copies of their units and use the *Unit Construction Checklist* to review Stage 1 of each other's units. Mentors circulate among the teacher pairs, listening in on the discussions and joining in as appropriate. Although mentors should not dominate the discussions, they can offer helpful comments, answer questions, and ask questions that they think should be addressed by the partners.

Goals

Completing this activity will help teachers to:

- Check Stage 1 of their unit for completeness
- Gain practice in using the Unit Construction Checklist
- Revise and improve Stage 1 of their unit

Materials

- ☐ *ESBD Unit Construction Checklist* Handout 50 (1 per teacher)
- ☐ Each participant needs two printed copies of his/her unit

Approximate Time

60 minutes

Procedure

1. Each teacher should print two copies of their unit. (Printing should probably start during the immediately preceding break.)
2. Teachers get into partner pairs and exchange units.
3. Each takes 15-20 minutes to review their partner's unit using the *Unit Construction Checklist*, noting places where the unit meets the expectations and places where it needs improvement.
4. Teachers get together as a pair and take turns giving feedback on the unit they reviewed. Each makes notes on changes they want to make to their own unit.
5. In the remaining time, teachers can work on making changes to their units and may want to engage in discussions with their mentors.

HANDOUT 58

Reflection Day 7 Afternoon

Name: _____ Date: _____

Share something that you feel particularly good about in your unit design.

Comment on the process of using the Unit Checklist with your partner to evaluate Stage 1 of your unit. What did this review process help you see about your unit that you might not otherwise have noticed?

DAY 8

Introduction

Day 8 Overview

This day is devoted to teachers working on the design of Stage 2 of their Earth science units. Mid-morning features a video interview of experienced ESD design teachers sharing the challenges of Stage 2 ESD design and teaching, followed by group discussion of the video. The day concludes with a review of Stage 2 of the units using the Unit Checklist. Throughout the day, staff mentors circulate and assist teachers with their unit design.

Day 8 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners begin work on Stage 2 of units
10:00-10:15	Break
10:15-11:00	Challenges of Stage 2: video of ESD teachers followed by discussion
11:00-11:45	Partners continue work on Stage 2 of units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners continue work on Stage 2 of units
2:00-2:15	Break
2:15-3:15	Check units for completeness of Stage 2
3:15-3:30	Reflection

ACTIVITY 27

Challenges of Stage 2: Assessment Video and Discussion

Description

For this activity, teachers view and then discuss a video of experienced ESBD teachers relating their experiences implementing the assessment approaches of ESBD.

Goals

Completing this activity will help teachers to:

- Understand how implementing ESBD changed the thinking and behavior of two teachers
- Understand how implementing ESBD changes one's approach to assessment
- Understand how ESBD's new approach to assessment may affect students

Materials

- ☐ *Teacher Reflections: Reports from the Field* DVD
- ☐ *Video Discussion Questions: Part 2* Handout 59

Approximate Time

45 minutes

Procedure

In this segment of the video, Anne and Sam discuss how ESBD has influenced their approach to assessment and how that has affected their students.

1. Hand out the *Video Discussion Questions: Part 2*.

Explain that teachers may use the discussion question sheet to take notes if they wish and that they will be discussing these questions after the video.

2. Show the video.

Show the third chapter *Challenges of Stage 2*.

3. Discuss the video as a whole group.

Use the discussion questions on the handout, but, of course, additional questions may come up for discussion.

HANDOUT 59

Video Discussion Questions: Part 2

Challenges of Stage 2: Assessment (about 9 minutes)

How does Sam use information about student misconceptions differently now?

What does Anne say about how she deals differently with assessment?

What do they say about how ESD affects different kinds of students?

HANDOUT 60

Reflection Day 8 Morning

Name: _____ Date: _____

Please share any insights about ESBD and assessment that you gained from the video.

ACTIVITY 28

Check Units for Completeness of Stage 2

Description

Working with their partners, teachers exchange printed copies of their units and use the *Unit Construction Checklist* to review Stage 2 of each other's units. Mentors circulate among the teacher pairs, listening in on the discussions and joining in as appropriate. Although mentors should not dominate the discussions, they can offer helpful comments, answer questions, and ask questions that they think should be addressed by the partners.

Goals

Completing this activity will help teachers to:

- Check Stage 2 of their unit for completeness
- Gain practice in using the *Unit Construction Checklist*
- Revise and improve Stage 2 of their unit

Materials

- ☐ *ESBD Unit Construction Checklist* Handout 50 (1 per teacher)
- ☐ Each participant needs two printed copies of his/her updated unit

Approximate Time

60 minutes

Procedure

1. Each teacher should print two copies of their unit. (Printing should probably start during the immediately preceding break.)
2. Teachers get into partner pairs and exchange units.
3. Each takes 15-20 minutes to review their partner's unit using the *Unit Construction Checklist* Handout 50, noting places where the unit meets the expectations and places where it needs improvement.
4. Teachers get together as a pair and take turns giving feedback on the unit they reviewed. Each makes notes on changes they want to make to their own unit.
5. In the remaining time, teachers can work on making changes to their units and may want to engage in discussions with their mentors.

HANDOUT 61

Reflection Day 8 Afternoon

Name: _____ Date: _____

What was your greatest struggle as you worked on your unit today?

DAY 9

Introduction

Day 9 Overview

This day is devoted to teachers working on the design of Stage 3 of their Earth science units. Mid-morning features a video interview of experienced ESBD teachers sharing the challenges of Stage 3 ESBD design and teaching, followed by group discussion of the video. Throughout the day, staff mentors circulate and assist teachers with their unit design.

Day 9 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners begin work on Stage 3 of units
10:00-10:15	Break
10:15-11:00	Challenges of Stage 3: video of ESBD teachers followed by discussion
11:00-11:45	Partners continue work on Stage 3 of units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Partners continue work on Stage 3 of units
2:00-2:15	Break
2:15-3:15	Partners continue work on Stage 3 of units
3:15-3:30	Reflection

ACTIVITY 29

Challenges of Stage 3: Learning Activities Video and Discussion

Description

For this activity, teachers view and then discuss a video of experienced ESBD teachers relating their experiences implementing learning activities in ESBD.

Goals

Completing this activity will help teachers to:

- Understand how implementing ESBD changed the thinking and behavior of two teachers
- Understand how implementing ESBD changes one's approach to content
- Understand how ESBD's new approach to the goals of learning may affect students

Materials

- ☐ *Teacher Reflections: Reports from the Field DVD*
- ☐ *Video Discussion Questions: Part 3 Handout 62*

Approximate Time

45 minutes

Procedure

In this segment of the video, Anne and Sam discuss how ESBD has influenced their selection of activities, their teaching of Earth science content, and how that has affected their students.

1. Hand out the *Video Discussion Questions: Part 3*.

Explain that teachers may use the discussion question sheet to take notes if they wish and that they will be discussing these questions after the video.

2. Show the video.

Show the chapter *Challenge of Stage 3*.

3. Discuss the video as a whole group.

Use the discussion questions on the handout, but, of course, additional questions may come up for discussion.

HANDOUT 62

Video Discussion Questions: Part 3

Challenges of Stage 3: Learning Activities

What do Anne and Sam identify as the challenges of implementing the ESD approach?

How did Anne cope with some of the anxieties of implementing the new approach?

HANDOUT 63

Reflection Day 9 Morning

Name: _____ Date: _____

Please share any thoughts about the video that you felt were particularly helpful. Be as specific as possible.

ACTIVITY 30

Check Units for Completeness of Stage 3

Description

Working with their partners, teachers exchange printed copies of their units and use the *Unit Construction Checklist* to review Stage 3 of each other's units. Mentors circulate among the teacher pairs, listening in on the discussions and joining in as appropriate. Although mentors should not dominate the discussions, they can offer helpful comments, answer questions, and ask questions that they think should be addressed by the partners.

Goals

Completing this activity will help teachers to:

- Check Stage 3 of their unit for completeness
- Gain practice in using the *Unit Construction Checklist*
- Revise and improve Stage 3 of their unit

Materials

- ☐ *ESBD Unit Construction Checklist* Handout 50 (1 per teacher)
- ☐ Each participant needs two printed copies of his/her updated unit

Approximate Time

60 minutes

Procedure

1. Each teacher should print two copies of their unit. (Printing should probably start during the immediately preceding break.)
2. Teachers get into partner pairs and exchange units.
3. Each takes 15-20 minutes to review their partner's unit using the *Unit Construction Checklist*, noting places where the unit meets the expectations and places where it needs improvement.
4. Teachers get together as a pair and take turns giving feedback on the unit they reviewed. Each makes notes on changes they want to make to their own unit.
5. In the remaining time, teachers can work on making changes to their units and may want to engage in discussions with their mentors.

HANDOUT 64

Reflection Day 9 Afternoon

Name: _____ Date: _____

How has the institute experience influenced your thinking about the scientific content that you teach?

HANDOUT 65

Reflection Day 10 Morning

Name: _____ Date: _____

If a colleague asked you how attending the ESBD Institute influenced the way you think about lesson planning and student learning, what would you tell them?

DAY 10

Introduction

Day 10 Overview

On the final day of the institute teachers complete the first draft of the Earth science units they will teach. First drafts are printed and distributed to all participants. Each teacher is assigned a specific staff mentor for the duration of the program and meets with the mentor to review the unit and establish their relationship. Teachers receive certificates of completion, review schedule for the rest of the year, complete the on-line reflection and celebrate the completion of the Institute.

Day 10 Schedule

8:30-8:45	Welcome and overview of the day
8:45-10:00	Partners continue work on Stage 3 of units
10:00-10:15	Break
10:15-11:45	Partners continue work on units
11:45-12:00	Reflection
12:00-12:45	Lunch
12:45-2:00	Teachers meet with their mentors Continue unit work Complete online reflection
2:00-2:15	Break
2:15-3:30	Institute Conclusion <ul style="list-style-type: none"> • Print and distribute first drafts of all units to everyone • Present certificates of completion • Review schedule for the rest of the year • Celebrate completion of Institute

ACTIVITY 31

Teachers Meet With Mentors

Description

Teachers meet with their mentors, complete the final online reflection, and continue work on their units.

Goals

Completing this activity will help teachers to:

- Begin to establish a relationship with their mentor
- Revise and improve their unit; make notes on future work that the unit needs
- Reflect on the Institute experience

Materials

- ☐ URL for the Online Questionnaire (to be provided to site leader by TERC)
- ☐ List of teachers and assigned mentors

Approximate Time

75 minutes

Procedure

1. Hand out or announce the list of mentors assigned to teachers. Explain that mentors have been assigned to teachers based on the site leader's judgment about which mentors and teachers would work well together. Explain that during the next 75 minutes, as teachers finish completing their online questionnaires they should meet with their mentors, exchange phone numbers and emails and addresses if necessary, and discuss how they will communicate. Mentors should leave the institute with a printed copy of the first draft of the units of their mentees.
2. Have teachers complete the final Online Reflection.
3. In the remaining time, teachers can work on making changes to their units and may want to engage in discussions with their mentors.

ACTIVITY 32

Workshop Conclusion

Description

In this final session, each teacher receives printed copies of the units of colleagues and a certificate of completion if you decide to have one. Teachers review the rest of the ESBD year and celebrate the completion of the Institute.

Goals

Completing this activity will help teachers to:

- Understand the schedule for the remainder of the ESBD year
- Receive recognition for their hard work
- Celebrate the completion of the Institute

Materials

- ☐ Printed copies of all teacher units (one set for each teacher and mentor)
- ☐ *Certificate of Completion* (optional, one for each teacher).
Download the certificate template from the ESBD web site. Customize and print one certificate for each teacher. Certificates should be signed by the institute leader.
- ☐ Schedule of the events during the remainder of the ESBD year (one per teacher), created by staff leaders.

Approximate Time

75 minutes

Procedure

1. During the preceding break, print one copy of each teacher's unit and begin the photocopying of them. Actually, you may need to have teachers stop work earlier on their units in order to have time to make the copies. Make one complete set for each teacher and mentor.
2. You may choose to have a "completion" or "graduation" ceremony, but bear in mind that the Summer Institute is only the beginning of the ESBD year so you are celebrating the completion of the first phase. You may wish to have each teacher come up to the front and receive a certificate of completion from the site leader and staff. It is a nice way to recognize the hard work the teachers have done.
3. Hand out and discuss the schedule of events for the remainder of the ESBD year. (You will create this yourself.) It should include dates for the posting and review of a second and possibly a third draft of the units, the Fall Conference dates and location, and the Spring Conference dates and location.

ACTIVITY 32 Workshop Conclusion - Page 2

4. Allow time in a whole-group discussion for teachers, staff, and leaders to share some final thoughts or reflections on the Summer Institute experience. A good question, we have found, to promote discussion and sharing is the same question used in the final online reflection: “What enduring understanding do you leave the Institute with?” If you have the capability to do so, record this final discussion on videotape, giving each teacher a chance to speak individually to the camera.
5. You may wish to adjourn to a restaurant or other location for informal celebrating!

HANDOUT 66

Reflection Day 10 Afternoon

Name: _____ Date: _____

What enduring understanding do you leave the institute with?

Mentoring and Coaching Guide

APPENDIX A

Mentoring and Coaching in Earth Science by Design

Introduction

Mentoring is an essential element of the Earth Science by Design Program (ESBD). Beginning at the summer institute each teacher is paired with a staff mentor. These partnerships enhance the self-worth and growth of both participants and staff, provide support, and promote the sharing of ideas in the development of a unit using the Understanding by Design (UBD) approach. In addition, during the summer institute each teacher is paired with another teacher who serves as a partner and peer coach for the program year.

As staff mentors work closely with their teachers, a mutual reliance can begin to grow, and the fear of change diminishes, replaced by the joy and challenge of learning and growth. Mentoring in ESBD can enhance teachers' confidence in their own judgment and their willingness to take informed, calculated risks, risks that are present anytime change is required in teaching and learning.

General Goals for Mentoring and Peer Coaching in ESBD

- Develop a long-term collaborative environment of support and encouragement for ESBD participants.
- Build collegiality, trust, and respect between staff and ESBD participants.
- Help diminish the sense of isolation that most teachers experience by offering a team approach for developing curricular units.
- Promote the UBD approach in curriculum organization and best practice in Earth science education.
- Provide positive, descriptive, non-judgmental feedback for the revision of ESBD units.
- Facilitate a professional vision of Earth science teaching and learning.

Logistics

ESBD participants leave the summer institute with a first draft of their unit. As they continue to work on their units after the institute, they post them on the ESBD Web site where all project participants can read them. They also post the time when they think they will implement their units in their classrooms. Units are generally taught during the Fall semester. Before the Spring conference a more polished unit is posted. Mentors initiate contact with their teachers before, during, and after the unit implementation. In addition, partner teachers are encouraged to stay in touch, to offer advice on each other's evolving units, and to exchange visits during the unit implementation.

Mentoring and Coaching Guide

Mentoring/Coaching During the Summer Institute

At the end of the first week of the Summer Institute, teachers choose their unit topic. They also identify two co-participants that they would be willing to partner with, usually someone at their own grade level, same school district, or someone working on the same topic. Institute staff create teacher pairs they judge to be beneficial and compatible.

- The institute leader assigns project staff as mentors to teachers using criteria such as staff expertise, participant requests, and learning and teaching styles.
- During week two of the summer institute mentors (and other staff) are available to their group of participants for consultation and guidance. This includes help in developing the scope of the unit and the alignment of its elements.
- Time is built into the schedule for teacher-partners to work together and give critical feedback as they develop their units during the second week.
- Staff facilitates the sharing of resources among the teachers, including the work of other participants and staff members, in order to create a collaborative working relationship.

NOTE: It is important that each participant work with one staff mentor for most of the unit development process to prevent confusion resulting from differing staff viewpoints and mentoring styles. It is not helpful for teachers at this stage of their work to hear conflicting or divergent opinions or advice from different staff members.

Coaching from the Summer Institute to the Fall Conference

The Fall Conference is designed as a forum where teachers can offer a second draft of their unit for review by their mentors and their partners. The following schedule of email or phone interventions is suggested to help participants achieve this goal.

- Teachers post the first draft of their units on the last day of the summer institute.
- Four weeks later, ESBD mentors log on to the Web site and check the status of the units for those participants they are assigned to.
- Mentors make suggestions to fill gaps in the unit, comment on various aspects of the unit's development, answer questions, and give support via e-mail or phone.
- This process is repeated four weeks later.
- Right before the Fall conference project leaders print out teachers' second drafts from the Web site for sharing at the Fall Conference.

Mentoring/Coaching from the Fall to the Spring Conference

After the ESBD Fall Conference, teachers implement their units. Teacher partners are encouraged to visit each other's classroom and do observations of each other's units. A classroom observation guide and also a completed example can be found in the appendix of this book and on the ESBD web site.

After their units are implemented, teachers modify their units using what they have learned during the implementation phase. We have found that teachers often need to change their units once they have actually taught the unit. Teachers must complete a finished product to display at the Spring Conference. To aid them in this process, we suggest the following schedule of mentoring:

- Mentors contact teachers by phone or email at the scheduled end of their implementation and discuss the unit's implementation. Here are some suggested questions that can prompt reflection:
 1. What was your overall impression of the execution of your unit?
 2. Were the essential questions helpful in guiding you and the students through the unit?
 3. Did you administer your preconception quiz? If so, what did you learn from it and how did you use that information?
 4. What surprised you the most about the implementation of your unit?
 5. How did your performance assessment work out?
 6. Next year, what would you change about your Stage 3 activities and assessments?
- Remind teachers that they will need to bring evidence of student work from their performance assessment to share with their peers at the Spring Conference.
- Direct teachers to the Implementation Report Guidelines on the ESBD Web site and remind them to have it completed before the Spring Conference begins.
- Four weeks before the Spring Conference, go online and check the status of participants' units. If further revisions need to be made, or if teachers have not revised them since their implementation, remind them to do so via email or phone. Offer help as needed.

Mentoring and Coaching Guide

Strategies for Effective Mentoring of ESDB Participants

Teachers, as well as workshop mentors, lead busy lives and there is rarely time for face-to-face discussion and tutoring. In ESDB, we have found that a systematic schedule of online coaching can be effective in moving teachers from first to second to final draft stages of their unit development.

In her book, *Mentoring Programs for New Teachers*, Susan Villani synthesizes others' lists of the attributes and characteristics of quality mentors.

- Approachability
- Integrity
- Ability to listen
- Sincerity
- Willingness to spend time
- Enthusiasm
- Teaching competence
- Trustworthiness
- Receptivity
- Willingness to work hard
- Positive outlook
- Confidence
- Commitment to the profession
- Openness
- Experience in teaching
- Tactfulness
- Cooperativeness
- Flexibility

Of course, in the online environment, it is sometimes difficult to exhibit all these attributes simultaneously! In ESDB, it is important for staff to emphasize what is right about a participant's unit rather than immediately commenting on what is wrong with it. You will find that most participants have their Stage 1 and 2 pretty much in order when they leave the summer institute, while Stage 3 might be in disarray or incomplete. Here are some specific items to look for during the first revision period (from Summer Institute to Fall Conference):

Mentoring and Coaching Guide

- Is the list of Essential Questions aligned with the Enduring Understandings?
- Are the tasks listed in “What Students Will Need to Know and Be Able to Do” aligned with the Essential Questions?
- Has the preconception quiz been written in the space provided in Stage 2?
- Does the Stage 2 performance assessment measure student understanding of the majority of the enduring understandings of the unit?
- Has the rubric for the Stage 2 performance assessment been completed?
- Are there any “hanging visualizations,” Internet resources listed in Stage 3 that are unconnected with an activity or demonstration?
- Have an adequate number of visualizations been used in Stage 3 activities?
- Have the pre- and post-conception quizzes been listed in the “W” and last “E” phase respectively?
- Has an effective activity or self-assessment quiz been used in the Reflection section of Stage 3?

Here are some specific items to look for during the second and third revision to the unit before submission of the “final product” at the Spring Conference. Be aware that changes may occur in the scope of the project and the Performance Assessment.

- Support participants as they make changes to reflect their classroom needs.
- Check alignment of all components since elimination of an essential question often means other elements of the unit should be omitted. (See list above).
- Make sure that the Spring Conference version of the unit reflects only those components actually completed.
- Encourage teachers to keep unused resources for another time.

Since curriculum is never truly finished, and the UBD approach is a new world for teachers, the impact of a staff person’s encouragement and support is invaluable.

Resources for Mentoring

1. Susan Villani, *Mentoring Programs for New Teachers: Models of Induction and Support*. 2002. Thousand Oaks, CA: Corwin Press.
2. Lipton, L., & Wellman, B., with Humbard, C. (2001). *Mentoring matters: A practical guide to learning-focused relationships*. Sherman, CT: Mira Via.
3. A Web site devoted to mentoring: The Mentoring Leadership and Resource Network, an affiliation of ASCD <http://www.mentors.net>.
4. Kathy Dunne, Anne Newton, et.al., *Mentoring: A Resource and Training Guide for Educators*, 1994, WestEd.

APPENDIX B

Misconceptions in Earth Science by Design: Uncovering and Changing Students' Naïve Ideas

Introduction

"Every time we communicate, new concepts compete with the preconceived ideas of our listeners. All students hold these ideas, but they are unaware of their private theories."

From the video "A Private Universe: Misconceptions That Block Learning."
Produced at the Harvard-Smithsonian Center for Astrophysics.

All students bring into our Earth science classrooms their own ideas of how the world works. When these ideas are mistaken, our task as science teachers is to help our students overcome them, giving learners at least a realistic notion of how Earth and its systems behave, react, and connect with each other. Students' preconceived notions are called preconceptions in some cases, *misconceptions* in others.

In ESBD, regarding Earth science concepts, we differentiate between student preconceptions and misconceptions. Preconceptions are ideas that can be corrected through ordinary educational interventions. Example: A student thinks that the North Pole is a land mass and then is told or shown that it is an ice sheet with water underneath it. Misconceptions are often abstract ideas that involve juggling multiple ideas in multiple dimensions. Example: A student believes that Earth being farther from or closer to the sun causes the seasons. To overcome this misconception, a student has to put together the following ideas: Earth's motion around the sun, the tilt of Earth's axis, heating effects, temperature changes, the length of time the sun is in the sky, and more. Misconceptions also tend to be strongly, sometimes tenaciously, held. Misconceptions in Earth science cannot be changed by the teacher proclaiming the "right answer" or by a student reading the correct answer in a textbook.

Instead, a series of conditions must be met to bring about conceptual change in students with respect to a concept that is a true misconception. Strike and Posner (1985) offer four conditions that must be met for conceptual change to occur:

- students must be dissatisfied with their existing view
- the new conception must appear somewhat plausible
- the new conception must be more attractive
- the new conception must have explanatory and predictive power

To effect a change in students' ideas, then, a model of conceptual change must be employed. The Model of Conceptual Change (MOCC), developed by many researchers (see Clement, 1987; Nussbaum & Novick, 1981; Driver & Scanlon, 1989; Posner, Strike, Hewson, 1983; Strike & Posner, 1985; Duit, 1987; and Stephans, 1991, et al) provides a structure that puts students in a position to confront their misconceptions and presents a systematic way to assist them in overcoming their naïve ideas. In ESBD, strategies to achieve each phase of this model are built into the design process, ensuring that conceptual change has a chance to take place.

Conceptual Change in Earth Science by Design

The first phase of the MOCC is that students must become aware of their preconceptions and expose their beliefs to others. Having students state and attempt to use their naïve ideas to make predictions BEFORE any discussion of the concept takes place establishes a solid foundation of self-awareness. In ESBD, students are given a preconception survey at the beginning of each unit. Writing their ideas down on paper serves two purposes: 1) It offers the teacher a window into students' minds and can help shape instruction of the unit. 2) The written survey becomes a permanent record of students' ideas that they can revisit at the end of the unit. Answering survey questions by sketching, drawing, and writing is preferable to simply having a general class discussion about student ideas. One good strategy for combining both types of assessment is to let students work in small groups and direct participants to explain to others their answers to survey questions. This allows each student the chance to compare his or her ideas to those of other students.

The second phase of the MOCC involves students confronting their ideas through a series of activities in which their beliefs can be tested and discussed, preferably in small groups. In ESBD, Stage 3 activities are organized to give students information about concepts using activities that employ different facets of understanding (explanation, application, perspective, interpretation, empathy, and self-knowledge). This approach helps students uncover inconsistencies between their mental models and the new ideas presented to them. In the WHERE model of Stage 3 construction, multiple approaches can be used to generate confrontations with the correct view of the world; students are helped to move toward a more enduring understanding of the concepts. Strategies such as posting the unit's essential questions, offering reflection activities that review the concepts, and giving frequent self-assessment quizzes sprinkled through the WHERE stages all serve this purpose. Also, in the final E phase of WHERE students do a post-conception survey and compare their answers to their initial effort at the beginning of the unit.

After confronting their beliefs and comparing them with new ideas, students now need to move to phase 3 of the MOCC and not only resolve the differences between new and old ideas, but also move toward the accommodation of the new concept. In ESBD, the Stage 2 performance assessment is used to gauge deep and enduring understanding of the misconceptions embedded in the unit's essential questions. Stage 2 performance assessment tasks such as modeling, journaling, designing, and organizing assists both students and teachers in assessing understanding and making connections among the many content, process, and concept strands in the unit.

Phase 4 in the MOCC requires that students extend and make connections between the concept learned and other concepts in both subject matter and their daily lives. In ESBD, the web of connections is developed as students explore other areas of Earth science, particularly if the course is being taught with an Earth systems approach. Concepts listed in Stage 1 as enduring understandings and essential questions are embedded in a hierarchy of connected thoughts and content strands. Many misconceptions are naturally linked with ever broader, interconnected ideas. The concept of density may be initially addressed in a unit on plate tectonics. Later,

the concept of density is central to a students' understanding of weather. Still later, students would be confronted with density again as the study of ocean currents is begun. In an ESD classroom, opportunities for enlightenment arise as a misunderstood concept reappears in another unit, often in a different context or perspective.

Moving through awareness, confrontation, and resolution of conflicts to the accommodation and extension of a newly understood concept is a path that some students will successfully traverse. Researchers in various studies find improvement to range from 5% to 60%, rarely higher, no matter how intensive the intervention and cognitive strategies employed. Project STAR, a full-year astronomy text and lab program structured and designed expressly for helping students overcome misconceptions, reported a gain of between 10% and 25% on such concepts as phases of the moon and seasons. So, the war on misconceptions requires to offer students opportunities for evaluating their ideas and comparing them against the true models and concepts of Earth science.

References

- Clement, J. (1987). Overcoming students' misconceptions in physics: the role of anchoring intuitions and analogical validity: In J. Novak (Ed.) *Proceedings of the Second International Seminar on Misconceptions and educational Strategies in Science and Mathematics* (Vol. 3). Ithaca, NY: Cornell University, pp. 84-97.
- Driver, R. & Scanlon, E. (1989). Conceptual change in science. *Journal of Computer Assisted Learning*, 5, pp. 25-36.
- Duit, R. (1987). Research on students' alternative frameworks in science—topics, theoretical frameworks, consequences for science teaching. In J. Novak (Ed.), *Proceedings of the Second International Seminar on Misconceptions and educational Strategies in Science and Mathematics* (Vol. 1). Ithaca, NY: Cornell University, pp. 151-162.
- Nussbaum, J. & Novick, S. (1981). Creating cognitive dissonance between students' preconceptions to encourage individual cognitive accommodation and a group cooperative construction of a scientific model. Paper presented to the AERA Annual Convention.
- Stepans, J. (1991). Developmental patterns in students' understanding of physics concepts. In S. Glynn, R. Yeany, & B. Britton (Eds.), *The psychology of learning science*. Hillsdale, NJ: Lawrence Erlbaum, Publishers.
- Posner, G., Strike, K., Hewson, P. & Gertzog, W. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change. *Educational Psychologist*, 28, (2) 265-277.
- Strike, K. & Posner, G. (1985). A conceptual change view of learning and understanding. In L. West & A. Pines (Eds.), *Cognitive structure and conceptual change*. Orlando, FL: Academic Press.

Other Resources on Misconceptions in Earth Science

Ault, C.R. Jr. (1984) *The Everyday Perspective and Exceedingly Unobvious Meaning*. Journal of Geological Education, 32, 89-91.

Barrow, L. and Haskins, S. (1996) *Earthquake Knowledge and Experiences of Introductory Geology Students*. Journal of College Science Teaching, 26 (2), 143-146.

Bezzi, A. and Happs, J.C. (1994) *Belief Systems as Barriers to Learning in Geological Education*. Journal of Geological Education, 42, 134-140.

Bendall, S., Goldberg, F., and Galili, I. (1993) *Prospective elementary teachers' prior knowledge about light*. Journal of Research in Science Teaching, 30, 1169-1187.

Brunkhorst, B. J. and Ramirez, D.L., (2001) *Perceptions of Geological Concepts Identified by AAAS for Geoscience literacy, K-12, held by pre-service and in-service teachers of science, pre and post instruction*. In *GSA Abstracts with Programs*, volume 33, number 6 (Annual Meeting), A-370.

Chang, C.-Y. and Baufaldi, J.P. (1997) *Initiating Change in Students' Achievement and Alternative Frameworks Through a Problem Solving Based Instructional Model*. Paper presented at the Annual Meeting of the National Association for Research in Science Teaching; Oakbrook, IL (22 March), 19 pp.

DeLaughter, J. E., Stein, S., Stein, C.A., and Bain, K.R. (1998a) *Preconceptions Abound Among Students in an Introductory Earth Science Course*. EOS, 79 (36), 429-432.

DeLaughter, J. E., Stein, S., Stein, C.A., and Bain, K.R. (1998b) *Rocks for Jocks: Preconceptions about the Earth*. Online. Available: <http://www.earth.nwu.edu/people/seth/Test> (visited 1998, December 1).

Galili, I., Bendall, S., and Goldberg, F. (1993) *The effects of prior knowledge and instruction on understanding image formation*. Journal of Research in Science Teaching, 30, 271-301.

Gilbert, J.K. and Watts, D. M. (1983) *Concepts, Misconceptions and Alternative Conceptions: Changing Perspectives in Science Education*. Studies in Science Education, 10, 61-98.

Gilbert, J.K., Watts, D.M., and Osborne, R.J. (1985) *Eliciting Student Views Using an Interview-About-Instances Technique*. In *Cognitive Structure and Conceptual Change*. Academic Press, 11-27.

Hestenes, D., Wells, M. and Swackhamer, G. (1992) *Force Concept Inventory*. The Physics Teacher, 30, 141-158.

Halloun, I. and Hestenes, D. (1985) *Common sense concepts about motion*. American Journal of Physics, 53(11), 1056-1065.

Kusnick, Judi (2000) *Conceptual blocks to understanding geology revealed through narrative assessment*. In *GSA Abstracts with Programs*, volume 32, number 7 (Annual Meeting).

- Magnusson, S., Borko, H., Krajcik, J. & Layman, J. (March 1992). *The relationship between teacher content and pedagogical content knowledge and student knowledge of heat and temperature*. Paper presented at annual meeting of the National Association for Research in Science Teaching, Boston, Massachusetts.
- Mazur, E. (1997) *Peer Learning*. Prentice-Hall: New York.
- McDermott, L.C. (1991) *What we teach and what is learned—closing the gap*. American Journal of Physics, 59, 301-315.
- Meyer, W.B. (1987) *Vernacular American Theories of Earth Science*. Journal of Geological Education, 35, 193-196.
- Myers, J. D. (2000) *Earth Science Test Bank (ESTB): A Student-focused, Web-based Assessment Mechanism*. In *GSA Abstracts with Programs*, volume 32, number 7 (Annual Meeting).
- Phillips, W.C. (1991) *Earth Science Misconceptions*. The Science Teacher, 58 (2), 21-23.
- Schoon, K.J. (1989) *Misconceptions in the Earth Sciences: A Cross-age Study*. Paper presented at annual meeting of the National association for Research in Science Teaching, San Francisco, CA (March).
- Schoon, K.J. (1995) *The Origin and Extent of Alternative Conceptions in the Earth and Space Sciences: A Survey of Pre-Service Elementary Teachers*. Journal of Elementary Science Education, 7, 27-46.
- Smith III, J.P., diSessa, A.A., Roschelle, J. (1991) *Misconceptions Reconceived*. (manuscript copy) Graduate School of Education, University of California, Berkeley.
- Sjoberg, S. and Lie, S. (1981) *Ideas about force and movement among Norwegian pupils and students, (mimeograph)*. Oslo: University of Oslo, Center for School Science.
- Sykes, M.L. and Klemm, E. (1997) *Using Assessment of Student Misconceptions about Earthquakes for More Effective Teaching*. GSA Abstracts with Programs, 29, 367.
- Treagust, D.F. (1988) *Development and use of diagnostic tests to evaluate students' misconception in science*. International Journal of Science Education, 10(2), 159-169.
- Vincentini-Missioni, M. (1981) *Earth and Gravity: comparison between adults' and children's knowledge*. Paper presented at the International Workshop of problems concerning students' representation of physics and chemistry knowledge. Padagogische Hochschule Ludwigsburg, September.

Fall Conference

FALL

Table of Contents

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

Fall Conference

FALL

Overview

The Fall Teacher Conference is designed as a forum where teachers can offer a second draft of their ESBD unit for review by their mentors and their partners. In addition, participants further their understanding of ESBD and UBD by considering the implications of research on learning, analyzing assessment instruments, and revisiting the facets of understanding. They plan for implementation by preparing to keep a journal during the teaching of their ESBD unit, discussing guidelines for peer observation, and examining the requirements for the final report and presentation they will make about their ESBD experience at the Spring Teacher Conference.

Goals

Attending the Fall Conference will help teachers to:

- Deepen their understanding of ESBD and UBD
- Obtain ideas for revising, reorganizing, and strengthening their ESBD unit
- Meet with their mentors and partners to review units and discuss improvements
- Prepare a plan for implementing their ESBD units in their classrooms

Conference Leaders Do Ahead:

- ☐ Send Letter and enclosures to teachers informing them of what to bring to the conference (sample letter included in the Appendix).
- ☐ Prepare a Conference Notebook for each participant. Include in the notebook:
 - The conference agenda
 - Photocopy of the ESBD unit of each participant (rubrics should be included or teachers reminded to bring them)
 - Photocopy of Chapter 2 of *How People Learn: Bridging Research and Practice*, found at <http://books.nap.edu/html/howpeople2/ch2.html>
- ☐ Download and review the Powerpoint presentations for this conference from the ESBD web site.
- ☐ Arrange for Internet connection and computer projection system.
- ☐ Post the ESBD Program Essential Questions in the main meeting room of the conference and refer to them periodically throughout the two days.

Note: As during the summer institute, the daily reflections will be found online, which is where teachers should fill them out. Paper copies are provided here only as a backup in case online access is impossible.

In preparation for the afternoon sessions, mentors should read through the units of their mentees. They also may wish to refer to the *ESBD Fall Conference Unit Checklist Handout 9* to help with providing feedback.

Fall Conference

DAY 1

FALL CONFERENCE

Day 1 Overview

The first morning activity introduces research findings from *Understanding How People Learn*. Participants discuss the article they read and its implications for teaching. The second activity reviews the summer institute ideas on assessing for preconceptions, building on the ideas presented in the article on how people learn. Participants review an exemplary preconceptions survey as well as their own preconceptions survey. They develop ideas for improving their own survey based on ideas and lessons learned from the sample provided. In the third activity, participants review concepts in Earth systems science by discussing quotations from *Dr. Art's Guide to Planet Earth*. In the afternoon, participants meet with their mentors and partners to review their units and to plan revisions. Those who wish to can participate in the Visualization Roundtable. The day concludes with an online reflection.

Day 1 Schedule

8:30-8:45	Welcome and Introduction
8:45-9:45	Understanding How People Learn: Implications for Teaching
9:45-10:45	Tapping into Preconceptions
10:45-11:00	Break
11:00-12:00	Adding Earth System Science perspective to your ESD Unit
12:00-1:00	Lunch
1:00-3:15	Meet with mentors and partners, optional participation in Visualization Roundtable
2:30-2:45	Break (casual, as needed)
3:15-3:30	Online reflection
3:30	Adjourn

Fall Conference

DAY 2

FALL CONFERENCE

Day 2 Overview

In the first activity, participants review the six facets of understanding and examine how the facets were employed in several ESBD units. Participants compare and contrast the rubrics that they have created to evaluate their Stage 2 performance assessments. Participants examine the guidelines for partner observations, think about how keeping a journal can help improve teaching, and look ahead to the implementation report they will prepare for the spring conference.

Day 2 Schedule

8:30-8:45	Welcome and Introduction
8:45-9:45	Aiming for Deep and Enduring Understanding: Looking at Units
9:45-10:45	Rubric Roundtable—sharing of teacher-created rubrics
10:45-11:00	Break
11:00-12:00	Implementing ESBD: Conducting Partner Observations, Keeping a Reflective Journal, and Sharing Your Experiences
12:00-1:00	Lunch
1:00-3:15	Meet with mentors and partners, optional participation in Visualization Roundtable
2:30-2:45	Break (casual, as needed)
3:15-3:30	Online reflection
3:30	Adjourn

ACTIVITY 1

Understanding How People Learn: Implications for Teaching

Description

In this activity, participants discuss Chapter 2 of *How People Learn: Bridging Research and Practice*. Prior to the conference, participants have been given the URL to access this chapter online so that they can read it ahead of time. This chapter is a summary of the main results of the larger report, *How People Learn: Brain, Mind, Experience, and School*, published by the National Academy of Sciences in 2000. Chapter 2 is highly condensed and compact. The staff member facilitating this discussion should be thoroughly familiar with the chapter and, if possible, should be familiar with the larger report.

The report highlights 3 major findings from research:

1. Students come to the classroom with preconceptions.
2. Deep understanding requires facts, context, and an organizational scheme.
3. Metacognition is essential to effective learning and should be a part of the instructional and learning environment.

Each of these findings has implications for teaching and for the design of classroom environments. This activity and the next will help teachers understand these implications and integrate this understanding with their ESD work. The current activity asks teachers to focus on metacognition, the nature of expertise and understanding, and the kinds of classrooms that foster deep and enduring understanding. The discussion of preconceptions is deferred until the next activity.

Goals

Completing this activity will help teachers to:

- Become aware of research on learning
- Think deeply about how students learn
- Reflect on the implications of research on learning for their Earth science teaching

Materials

- ☐ Chapter 2 of *How People Learn: Bridging Research and Practice*, found at <http://books.nap.edu/html/howpeople2/ch2.html> (print this and send it to teachers in advance or ask them to download and read it themselves. Also, provide a printed copy for each participant at the conference.)
- ☐ *Discussion Questions for Chapter 2 of How People Learn: Bridging Research and Practice*, Handout 1

Approximate Time

60 minutes

ACTIVITY 1 Understanding How People Learn: Implications for Teaching

Procedure

1. Present the goals of the activity.

Review the fact that the chapter they have read in preparation for the conference is a summary of the research reported in the larger book *How People Learn: Brain, Mind, Experience, and School*, published by the National Academy of Sciences. That book was an attempt by scholars to summarize what science knows about learning in a way that would be useful to teachers and educational policy-makers. Explain that it is hoped that they see parallels between the findings presented in the report and the work they have been doing in ESD.

2. Explain the procedure.

Explain that participants will be discussing the reading in small groups, using the discussion questions that have been made available to them previously.

3. Place participants into groups of four or five, distribute the question sheet, and assign each group a question.

If there are more than 3 groups, individual parts of Question 3 may be assigned to separate groups. Allow the groups forty minutes to discuss the questions. Encourage them to discuss as many questions as they have time, but let them know that their group will be reporting back only on their assigned question.

4. Small groups report back to the larger group.

Ask for one person from each group to report back to the larger group a summary of their group's discussion of their assigned question.

HANDOUT 1

Discussion Questions for Chapter 2 of How People Learn: Bridging Research and Practice

At the Fall Conference, you will discuss one of these questions in a small group with your colleagues. Come to the conference prepared to discuss each of the questions.

1. What is metacognition? What role does it have in teaching and learning, i.e. why is it important? How does an ESD approach to instructional design use metacognition to achieve deep and enduring understanding?

2. The chapter makes a distinction between the expert and the novice. How does an expert differ from a novice? What can we learn from the novice-expert distinction that will help us design instruction that helps students achieve deep and enduring understanding?

3. The authors of the chapter write that effective learning environments should be:
 - Knowledge-centered
 - Learner-centered
 - Assessment-centered and
 - Community-centered

How does the ESD approach to teaching and learning incorporate these recommendations?

ACTIVITY 2

Tapping Into Preconceptions

Description

In this activity, participants consider the purpose of the Preconception Survey, examine existing ones, and analyze the survey they created. They also examine and discuss the results of one teacher's pre- and post-conception surveys for an ESBD unit about the theory of plate tectonics.

Goals

Completing this activity will help teachers to:

- Understand the value of assessing for preconceptions
- Obtain ideas for revising and strengthening the Preconception Surveys they have created to accompany their ESBD units
- Reflect on students' pre- and post-conceptions and the implications for their teaching

Materials

- ☐ *Example ESBD Preconception Surveys Handout 3 to 6*
- ☐ *Preconception Survey Checklist Handout 2*
- ☐ *Tapping Into Preconceptions Powerpoint presentation*

Approximate Time

60 minutes

Procedure

- 1. Present the goals of the activity.**
Tell teachers that during this session they will be considering student preconceptions. They will:
 - Look at one example together
 - Analyze it using *Preconception Survey Checklist Handout 2*
 - Use the same checklist to analyze their own preconceptions survey
 - Break into small groups to develop revisions for their surveys
- 2. Conduct a whole-group discussion about the importance of assessing for preconceptions.**
Ask teachers why they think it is important to assess the preconceptions of their students at the beginning of an ESBD unit. To guide the discussion, refer to points made in the article they read for the previous activity (Chapter 2 of *How People Learn: Bridging Research and Practice*).
- 3. Have teachers look at the *Preconception Survey for the Unit Plan: Scientific Revolution: The Theory of Plate Tectonics Handout 3*.**
- 4. Display and discuss slides 1 through 24 of the Powerpoint Presentation, *Tapping into Preconceptions*.**
Scientific Revolution: The Theory of Plate Tectonics, contains a model preconception

ACTIVITY 2 Tapping Into Preconceptions - Page 2

survey. It reflects the type of survey ESDB participants should strive to produce. As you discuss it, point out how the enduring understandings, essential questions, and preconception survey items are aligned. Remind teachers that having students make sketches or diagrams to accompany their written responses can provide a more complete picture of students' thinking than text alone. Highlight the fact that although this survey does not cover all the enduring understandings, it does get at most of them. Point out that items on the Preconception Survey should not cover ideas that students likely know nothing about, nor ideas that students understand completely because this does not provide the teacher any useful information. The function of the Preconception Survey is to probe understanding and help guide teaching and learning.

Some of the questions on the survey may reflect ideas that build toward bigger concepts. For example, students' preconceptions about the ocean floor can directly influence the model of plate tectonics that they build from it. Thus, it is useful to know about these underlying ideas. Warn teachers to try to avoid becoming lost in the details of their units. A well-developed Preconception Survey does not dwell on low-level knowledge and skills, but rather focuses on the significant "building block" concepts.

Eliciting *misconceptions* is another important function of the Preconception Survey. The "*What do students typically misunderstand?*" section of the unit planner is a good starting place when formulating items for the Preconception Survey. A well-designed Preconception Survey can enable teachers to gain rich insights into student thinking. As an example of this, discuss some of the different preconceptions that students held in the plate tectonics unit as shown by the sample survey responses.

5. Have teachers analyze their own Preconception Surveys.

When you have completed the discussion of Slide 24, ask teachers to take out their own ESDB unit and the *Preconception Survey Checklist*. Ask them to look over the checklist and reflect on ways to improve their survey. How does their survey compare to the one they just examined?

6. Discuss the three sample Preconception Surveys from ESDB units and their own surveys.

Place teachers into groups of three or four. Inform them that they should compare and contrast each other's Preconception Surveys, referring to the additional example surveys as needed. Their goal is to provide each other with feedback that could help them to revise and strengthen their own surveys.

7. Reconvene the group as a whole.

Conduct a brief discussion of the revisions they plan to make. Ask for volunteers to discuss the kinds of changes they decided to make, if any, in their own Preconception surveys.

8. Display and discuss slides 25 through 39 of the PowerPoint Presentation, Tapping into Preconceptions.

Remind teachers that it is often useful to administer the Preconception Survey again to students at the end of their unit of study in order to reveal gains in their understanding. Completing the same survey a second time allows students to see changes in their understanding and to reflect on how these changes occurred. It also serves as a measure for the teacher of the success (or lack thereof) of the instructional sequence that has been followed. Use the examples in the Powerpoint presentation to discuss the shift in student conceptions by comparing the pre- and post-conception responses. Ask teachers to consider the implications of assessing for preconceptions and post-conceptions when teaching their units. Point out that using pre- and post-conceptions is part of developing an effective *suite* of assessments for Stage 2.

HANDOUT 2

Preconception Survey Checklist

1. Are the survey questions aligned with the unit's enduring understandings and essential questions?
2. Does the survey get at most of the unit's big ideas or at least tap those that students might have preexisting knowledge about?
3. Does the survey take account of what students typically misunderstand?
4. How well does the survey help to reveal student thinking and understanding?
5. Are the results of the survey likely to help the teacher plan the teaching of the unit?
6. Is the survey "student friendly?"

HANDOUT 3

Scientific Revolution: The Development of the Theory of Plate Tectonics: An ESD Unit (edited)

Unit Enduring Understandings:

The theory of plate tectonics was once a new idea; it is now widely accepted by most scientists because of the evidence that has been collected which supports it.

The earth's crust is made up of plates.

Continents are part of the earth's plates; when the plates move the continents also move.

Over millions of years the continuous movement of the Earth causes the continents (landmasses) to merge and divide repeatedly.

Unit Essential Questions:

How did the theory of plate tectonics evolve?

What is the mechanism that drives the movement of the continents? What is its fuel?

What allows the continents to move?

What evidence supports the theory of plate tectonics?

Why did competent scientists reject the idea of continental drift?

Why is this theory a revolution?

What do students typically misunderstand?

Students often think that:

Science is static.

Scientific data has only one interpretation.

Scientific theories are based on evidence that can be observed or measured directly.

Continents do not move.

Continental movement cannot be measured because it is so slow.

The continents are floating on the oceans and not attached to the crust.

The ocean floor is flat.

Earthquakes happen randomly.

The continents are plates.

The oceanic crust does not move.

Scientists have always believed that the plates move.

Scientists have always believed that sea floor spreading causes the plates to move.

Preconception Survey:

If you were looking down on the Earth from space 200 million years ago, what would it look like?

Draw what you think the ocean floor would look like if you could walk between North America and Europe.

Describe what is under the continents.

Describe what happens to the ocean floor when the continents move during continental drift.

What allows the continents to move?

Where does the energy needed to move the continents come from? Explain how this energy moves the continents.

HANDOUT 4

Earthquakes and Volcanoes: An ESD Unit (edited)

Unit Enduring Understandings:

Volcanoes and earthquakes indicate the high temperatures and pressures that exist in earth's interior.

Studying historical earthquakes and volcanic eruptions improves our understanding of earth's processes.

Volcanism and seismic activity vary across the globe.

Although it is known where earthquakes and volcanic eruptions are likely to happen, there is currently no reliable way to predict precisely when an event will occur.

Unit Essential Questions:

What do earthquakes and volcanoes tell us about what is happening inside the earth and on the surface?

Can we predict earthquakes? Can we predict when volcanoes will erupt?

Do you have to worry about a volcanic eruption or earthquake where you live? Why or why not?

What do students typically misunderstand?

Students often think that:

Earthquakes occur when whole plates slide past each other.

Earthquakes create a gap or hole in the earth's surface.

Earthquakes occur at one depth.

Lava that erupts out of a volcano originates from earth's core.

Earthquakes cause volcanic eruptions.

Plate boundaries are the same as faults.

Lava comes out of all volcanic eruptions.

Preconception Survey:

Why do you think there are or are not earthquakes in Massachusetts?

What causes earthquakes?

Why do you think there are or are not volcanoes in Massachusetts?

What causes volcanoes?

Can we predict when an earthquake will happen?

Can we predict when a volcano will erupt?

Where do earthquakes happen in the earth?

Where does lava come from?

HANDOUT 5**Global Warming: What is It and What Can We do About It? An ESD Unit (edited)****Unit Enduring Understandings:**

There is a delicate balance between the energy of the sun and the atmosphere. This balance allows the Earth to maintain a temperature at which life as we know it can thrive.

The actions of human beings, both deliberate and unintentional, are changing the atmosphere. This affects the future of the Earth.

The ability of human beings to collect data and to decode the Earth's atmospheric patterns grows daily through use of sophisticated technology. Scientists are constantly making new discoveries and theories.

Unit Essential Questions:

How big is the atmosphere? How strong is it?

What takes care of what? Does the atmosphere take care of humans? Do humans take care of it? Can the atmosphere take care of itself?

The atmosphere has changed over time. What does its future hold?

What do students typically misunderstand?

Students often think that:

- The greenhouse effect is bad.
- The greenhouse effect is created by human beings.
- Global warming has to do with daily weather rather than long-term climate.
- There is no support for the idea of global warming.
- There is nothing that can be done about global warming.
- The ozone hole is responsible for global warming.
- The atmosphere goes on forever, or, it does not exist.

Preconception Survey:

1. If you could fly and you went straight up, what do you think you would find? What would happen to your body? Could you breathe? Would you get hot or cold? How far would you get before things started happening?
2. How do you think our planet Earth will change in your lifetime? In your children's lifetime? Will the temperature or weather change? How?
3. What have you heard or what do you think you know about global warming?

HANDOUT 6

Daily Weather: An ESD Unit (edited)

Unit Enduring Understandings:

Weather changes constantly with changes in air temperature, moisture content, and air pressure.

The importance of weather in our daily lives has led us to develop technology to constantly collect data and track weather systems around the globe.

Movement of and interactions between air masses result in changes in the weather.

Clouds provide information about what is taking place in the atmosphere.

Unit Essential Questions:

Why is weather so important to us?

How do temperature and pressure affect the movement of air?

How do differences in water vapor content, pressure, and temperature result in changes in weather?

What relationships exist between the weather and types of clouds?

What do students typically misunderstand?

Students often think that:

All clouds are the same.

Predicting weather should be easy.

Clouds and fog are not the same.

Air is uniform in temperature, pressure, and water vapor.

Changes in air temperature are gradual.

Any condensation in the atmosphere results in precipitation.

Preconception Survey:

How does weather affect our daily activities?

The weather is on TV, radio, etc. many times a day. Where does the information about weather come from?

What causes the weather to change?

What causes changes in temperature, not over the course of a year, but over the course of a week?

How do clouds form and what can they tell us about the weather?

ACTIVITY 3

Adding Earth System Science Perspective to your ESD Units

Description

In this activity, participants discuss selected quotes from *Dr. Art's Guide to Planet Earth*. Each of the quotes exemplifies understanding the Earth system through the facet of perspective. After analyzing the quotes, teachers discuss ways in which they might incorporate perspective into their Earth science teaching.

Goals

Completing this activity will help teachers to:

- Think deeply about Earth system science concepts
- Incorporate the facet of perspective into their Earth science teaching

Materials

- ☐ Understanding Cube (large demonstration version)
- ☐ *Reviewing the Six Facets of Understanding* Handout 7
- ☐ *Dr. Art's Guide to Planet Earth*
- ☐ *Perspective and ESD* Handout 8

Approximate Time

60 minutes

Procedure

1. Briefly review the six facets of understanding.

Hold up the large demonstration Understanding Cube and remind participants that the facets provide a framework for thinking about understanding. They help us to move beyond simply knowing the facts of Earth science and towards a deeper more enduring understanding. Point to one of the facets on the cube. Ask participants to explain what that facet means. Review each of the facets, but save perspective for last. After all the facets have been discussed, call attention to *Reviewing the Six Facets of Understanding* Handout 7 containing definitions of the facets.

2. Present the goals of the activity.

Emphasize that this activity focuses on understanding through the facet of *perspective*. Explain that participants will be examining quotes from *Dr. Art's Guide to Planet Earth*, discussing Earth system science concepts and considering ways in which they might incorporate the facet of perspective into their Earth science teaching.

ACTIVITY 3 Adding Earth System Science Perspective to your ESBD Units - Page 2

3. Place participants into groups of four or five, ask them to take out *Perspective and ESBD* Handout 8 from their notebooks, and inform participants that they will be discussing two topics, listed as items 1 and 2 on the discussion sheet. Encourage participants to take a few minutes to read through the quotes before they discuss them. Hold up *Dr. Art's Guide to Planet Earth* and suggest that they may wish to refer to information in the book for additional ideas. Allow the groups twenty minutes per discussion topic.
4. **Small groups report back to the larger group.**
Ask for one person from each group to report back to the larger group on key ideas from their discussions.
5. As participants share new ways to incorporate the facet of perspective into their teaching, list these on an overhead, whiteboard, or other display area.

HANDOUT 7**Reviewing The Six Facets of Understanding -
Definitions from Understanding by Design****Explanation**

Sophisticated and apt understandings and theories, which provide knowledgeable and justified accounts of events, actions, and ideas.

Interpretation

Narratives and translations that provide meaning.

Application

The ability to use knowledge effectively in new situations and diverse contexts.

Perspective

Critical and insightful points of view.

Empathy

The ability to identify with another person's feelings or worldviews.

Self-Knowledge

The wisdom to know one's ignorance and how one's patterns of thought and action inform as well as prejudice understanding.

HANDOUT 8

Perspective and EBSD

1. Each of these quotes from Dr. Art's book provides understanding through the facet of perspective. Pick one or more of these quotes and refer to the book as necessary to help you discuss how the quote uncovers a deep understanding about the Earth system. (20 minutes)

"The water that we drink connects us ultimately with the living beings that inhabited the planet before us, that inhabit Earth today and that will inhabit it in the future."
Pg. 33

"... the different reservoirs of the water cycle can differ greatly in the amount of water they contain. They also differ in the rate at which it enters and leaves. ... a water molecule stays in the ocean about 3,000 years, while it stays in the atmosphere only 9 days. The same water cycles over and over through the various reservoirs." Pg. 30

"Earth has dry land because the processes that build mountains balance the erosion processes. In the course of just 18 million years, the continents would be reduced to sea level and oceans would cover the Earth." Pg. 24

"Compared to the geosphere and hydrosphere, the atmosphere is the most sensitive and changeable of Earth's 'spheres'. It can change quickly because it is comparatively very small. In terms of mass, the whole Earth system contains a million times more solid stuff than gas. Therefore, if a small part of Earth's solid stuff changes to gas and enters the air, it can have a major effect on the atmosphere." Pg. 34

"The global carbon cycle is currently not in balance. ... Approximately 6 billion tons of carbon in the form of carbon dioxide enters the atmosphere due to the burning of fossil fuels for transportation, heating, cooking, electricity, and manufacturing." Pg. 41

"From a systems point of view, Earth is essentially a closed system with respect to matter." Pg 11

"From a systems point of view, Earth is essentially an open system with respect to energy." Pg 13

2. Discuss how you might incorporate the facet of perspective into your Earth science teaching. (20 minutes)

ACTIVITY 4

Meet with Mentors

Description

During this session, mentors support teachers in their curriculum design efforts by making suggestions to fill gaps in the unit, commenting on various aspects of the unit's development, answering questions, and encouraging them with positive remarks. (Mentors will have read through the units prior to the conference).

Goals

Completing this activity will help teachers to:

- Strengthen their ESBD unit plans
- Identify the final revisions they need to make on their ESBD plans prior to implementation

Materials

- ☐ Two copies of each participant's unit plan
- ☐ *ESBD Fall Conference Unit Checklist Handout 9*

Approximate Time

60 minutes

Procedure

1. **Announce that mentors will meet individually with participants during a block of time set aside for reflecting on ESBD unit plans.**

The primary goal of this meeting is to help participants discuss their unit as a whole and identify the final revisions that they need to make to their ESBD plans prior to implementation.

2. **Have teachers remove *Unit Checklist Handout 9* from their notebooks.**

Inform participants that mentors will be using this sheet to guide the discussion of their units. Suggest that teachers look over the questions, self-assessing their units. In addition participants should make note of specific questions or issues they would like to discuss with their mentors.

3. **Teachers reflect on units individually and with mentors.**

In ESBD, it is important for staff to emphasize what is right about a participant's unit, rather than immediately comment on what is wrong with it. Mentors should begin discussions by pointing to existing strengths in participants' plans. Mentors should remind participants that they are always available and, if appropriate, suggest they confer with others working on similar topics or struggling with the same issues. For plans that satisfy the guiding questions, mentors should help participants to streamline their plans.

HANDOUT 9

ESBD Fall Conference Unit Checklist

Assessing the Unit Components:

- ☐ Is the list of *Essential Questions* aligned with the *Enduring Understandings*?
- ☐ Are the tasks listed in *What Students Will Need to Know and Be Able to Do* aligned with the *Essential Questions*?
- ☐ Has the *Preconception Quiz* been written in the space provided in Stage 2?
- ☐ Does the Stage 2 performance assessment measure student understanding of the majority of the enduring understandings of the unit? Could students do well on the assessment without completing the unit (false positive)?
- ☐ Has the rubric for the Stage 2 performance assessment been completed?
- ☐ Are there any visualizations or other Internet resources listed in Stage 3 that are unconnected with an activity or demonstration?
- ☐ Have an adequate number of visualizations been used in Stage 3 activities?
- ☐ Have the Pre- and Post-conception Quizzes been listed in the W and last E phase respectively?
- ☐ Has an effective activity or self-assessment quiz been used in the Reflection section of Stage 3?
- ☐ Check the alignment of all components since elimination of an essential question often means other elements of the unit should be omitted.

Assessing Overall Structure and Implementation:

- ☐ How does this unit fit with the other units taught this year?
- ☐ What is the schedule for teaching this unit? Is there sufficient or too much material for this time frame?
- ☐ How are students going to be made aware of the goals of the units (posting essential questions, etc.)?
- ☐ Are there issues regarding needed materials? If so, can substitutions be made?

Questions or Issues to Discuss with Mentor

ACTIVITY 5

Visualization Roundtable

Description

In this activity, participants share visualizations that they have included in their ESBD unit plans. Each teacher selects one visualization from their unit and makes a brief presentation to the group. They describe the way in which they are using the visualization within the context of the WHERE model. They demonstrate and explain how the visualization works. Then they provide a rationale for having incorporated the visualization into their unit by highlighting the facet or facets of understanding that they feel the visualization gets at. (Depending on the speed of the Internet connection, it may be necessary to preload the visualizations prior to teachers' presentations.)

Goals

Completing this activity will help teachers to:

- Recognize effective visualizations that support Earth science understandings
- Reflect on the role of visualizations in their ESBD units

Materials

- ☐ Teachers' Online Unit Plans (with live access to the Internet and a projection device)
- ☐ URL for teacher visualizations, if not included in their plans
- ☐ *Visualization Sharing Guidelines* Handout 10

Approximate Time

60 minutes or longer, depending upon the number of participants

If there are a large number of participants, this activity can be shortened by only sharing some of the participants' visualizations.

Procedure

1. Present the goals of the activity.

Tell teachers that during this session they will be sharing one visualization with their peers. The session provides an opportunity for teachers to preview visualizations gathered by their peers, learning from each other as they reflect on the role of visualizations in promoting deep and enduring understanding.

2. Ask teachers to look at *Visualization Sharing Guidelines* Handout 10 and remind them that their presentations should address the questions on the sheet and be about three to five minutes long.

(Note: the guiding questions were sent to teachers previously in the letter they received about the Fall conference.)

ACTIVITY 5 Visualization Roundtable - Page 2

3. Call on teachers to make presentations.

If needed, guide the presentations by referring back to the sharing guidelines. It may be necessary to directly ask teachers those questions they did not cover. Allow a few minutes for questions from peers.

4. Thank teachers and draw the session to a close.

Thank teachers for sharing their visualizations. Tell the teachers that it is hoped that each of them learned of at least one new visualization today and that they have come away with an increased awareness of how visualizations can promote deep and enduring understanding in Earth science. Encourage teachers to “mine” each other’s units in the future when looking for effective visualizations.

Visualization Sharing Guidelines

1. Demonstrate how the visualization works (how one uses it).

2. Explain how you are planning to use the visualization in your unit (as a hook, reflection, review, etc.). What enduring understanding does it target?

3. Explain how it promotes deep and enduring understanding through a facet of understanding.

HANDOUT 11

Reflection Day One

Name: _____ Date: _____

What new insights have you had about how to help students achieve deep and enduring understandings in Earth science?

What new ideas or strategies that came up today might you want to incorporate into your teaching?

ACTIVITY 6

Aiming for Deep and Enduring Understanding

Description

In this activity, teachers examine several ESBD units to uncover the facets of understanding employed within the units.

Goals

Completing this activity will help teachers to:

- Strengthen the connection between the six facets of understanding and their use in ESBD units to move students toward deeper understandings

Materials

- ☐ Copies of two completed units per group
- ☐ *Summary Sheet for “Aiming for Deep and Enduring Understanding” Activity*
Handout 12 on transparency – one per group
- ☐ Powerpoint presentation *Aiming for Deep and Enduring Understanding*
- ☐ Overhead transparency projector

Approximate Time

60 minutes.

Procedure

1. Review the six facets of understanding.

Use the Powerpoint presentation for Activity 6 to show how each facet can be used as the basis for a Stage 3 activity. The examples were drawn from three teacher units about moon phases and address the following enduring understanding:

Understand how the relative movements of the Earth, moon, and sun account for the observed moon phases.

2. Break teachers into groups of four.

Give each group four copies of two different units.

3. Inform teachers that they are going to be looking for Stage 3 activities in these two units that effectively use the six facets of understanding to promote deep and enduring understanding.

Teachers should read the Enduring Understandings of each unit and then scan their Stage 3s for good examples of activities that employ one of the six facets. In order to get a sense of which facets they used the most, suggest that teachers keep a tally of how many activities they find per facet.

4. Instruct teachers to fill out a *Summary Sheet* Handout 12 for their group to use as a report-back tool.

They should select the best activities and try to find at least one activity per facet.

5. After 30 minutes, have a representative from each group share their group's summary sheet using an overhead or computer.

6. Lead a concluding discussion.

Ask teachers, “Which of the six facets of understanding was used the most in the units they studied? Which one was employed the least?”

Follow up with the question, “Why is it important to use as many of the six facets as you possibly can when designing Stage 3 of an ESBD unit?”

HANDOUT 12

Summary Sheet for “Aiming for Deep and Enduring Understanding” Activity

Unit Enduring Understanding	Facet of Understanding	Brief Description of Activity
	Explanation	
	Interpretation	
	Application	
	Perspective	
	Empathy	
	Self-Knowledge	

HANDOUT 13**Example Activities for the Six Facets of Understanding****Facet****Sample Activity****Explanation**

Students use a light bulb (the sun) and an orange (the moon) to give an explanation of how the moon phases are formed from the perspective of the Earth (their head).

Interpretation

Students research historical explanations of the phases of the Moon (e.g. Aristotle, Plutarch, cultural stories, etc.)

Application

Students are given Galileo's original 1612 drawing of the phases of Venus. Using a light bulb and an orange, students verify these observations and document the relative positions of the sun, Venus, and Earth that produce these phases.

Perspective

Students are shown a picture of the Earth from the moon when the Earth is in a waning gibbous phase and then they discuss the relationship of the sun-Earth-moon positions that account for Earth's appearance.

Empathy

Students consider the following scenario: A visitor from another planet, a female alien named Myrna, visited your school last weekend. Myrna's planet has no moons orbiting it. Put yourself in Myrna's place. What might it be like to live on a planet without a moon? How might life on Earth be different without a moon?

Self-Knowledge

Students in small groups compare their postconception quiz with their preconception quiz and discuss how their answers changed.

ACTIVITY 7

Rubric Roundtable

Description

In this activity, participants share the rubrics that they have created to evaluate their Stage 2 performance assessments. In small groups, teachers compare and contrast each other's rubrics. They examine the attributes, levels of performance, indicators, and weighting (if any) within each rubric. Teachers provide each other with feedback and make suggestions for revising their rubrics. Each group shares two insights from their discussions with the larger group.

Goals

Completing this activity will help teachers to:

- Obtain ideas for revising and strengthening the rubrics they have created to accompany their ESBD performance assessments
- Reflect on assessment issues

Materials

- ☐ Copies of teacher ESBD Unit Plans (one for each teacher)
- ☐ Copies of teacher rubrics (one for each teacher)
- ☐ Transparency of *Volcanic Eruptions Rubric Construction* Handout 14

Approximate Time

60 minutes

Procedure

1. Present the goals of the activity.

Tell teachers that during this session they will be sharing with their peers the rubric that they created to evaluate their performance assessment. The session provides an opportunity for teachers to compare and contrast rubrics, learning from each other as they discuss and reflect on assessment issues.

2. Review the key features of a rubric.

Display the transparency of *Volcanic Eruptions Rubric Construction* Handout 14 and point to the attributes, levels of performance, indicators, and weights while briefly reviewing their functions. Remind teachers that each of them has since had an opportunity to design their own rubric for their ESBD performance assessment.

3. Place teachers into small groups and provide discussion directions.

Place teachers into groups of three or four. Remind them that in order to provide feedback on each other's rubrics, it will be helpful for each of them to start by referring to their unit enduring understandings and then briefly describe their performance assessments. Their task will be to compare and contrast their rubrics and provide each other with suggested revisions.

ACTIVITY 7 Rubric Roundtable - Page 2

4. Together with other staff members, facilitate the small group discussions.

Encourage teachers to reflect on assessment issues as they arise within the groups. One probing question to ask groups might be, “Is it possible for students to receive a high score when assessed with this rubric, yet still not exhibit deep understanding?”

5. Ask one participant from each group to share two insights from their discussions.

These might include comments about the structure of their rubrics (such as common attributes or indicators) or issues pertaining to using rubrics with students (such as the best time to share them or the level of detail needed for students).

HANDOUT 14

Volcanic Eruptions Rubric Construction

Attributes	Levels of Performance				Weight
	1	2	3	4	
Geologic story	Incomplete or inaccurate geology content	Somewhat accurate geology content	Mostly accurate content	Geology content accurate and complete	
Eruption prediction supported by evidence	No evidence or misapplied evidence	Some evidence supports prediction	Most evidence supports prediction	All evidence clearly supports prediction	
Maps and visuals that support the presentation	Maps and visuals used decoratively	Maps and visuals somewhat support the presentation	Maps and visuals mostly support the presentation	All maps and visuals appropriately support presentation	
Emergency response based on prediction	Response is not based on prediction	Response somewhat based on	Response mostly based on prediction	Response based prediction completely on prediction	
Communication	Presentation is difficult to follow and is incomplete of Pangaea	Presentation is difficult to follow but is complete	Presentation is well structured, well articulated, but incomplete	Presentation is well structured, well articulated, and complete	

ACTIVITY 8

Implementing ESBD: Conducting Partner Observations, Keeping a Reflective Journal, and Sharing Your Experiences

Description

In this session, teachers examine guidelines for observing each other during the teaching of an ESBD lesson. Teachers also consider ways to structure journal entries so that they may use them to inform and guide the teaching and learning process. Last, they preview the ESBD implementation and presentation report guidelines for the Spring Conference.

Goals

Completing this activity will help teachers to:

- Provide feedback to their peers during classroom observation of an ESBD lesson
- Keep a journal that encourages self-reflection on the ESBD process
- Share their implementation experiences

Materials

- ☐ *Journaling for Self-Reflection* Handout 15
- ☐ *Classroom Observation Guide* Handout 17
- ☐ *Classroom Observation Guide Instructions for Partners* Handout 18
- ☐ *Example of “Running Notes”* Handout 19
- ☐ *Classroom Observation Guide Completed Sample* Handout 20
- ☐ *Implementation Report Guide* Handout 21
- ☐ *Spring Conference Presentation Guide* Handout 22

Approximate Time

30 minutes

Procedure

1. Conduct a discussion of the ESBD unit implementation process.

Remind participants that in the coming months they will be teaching (implementing) the ESBD units they have created. Being observant and reflective during this process is part of their professional development. When they reconvene for the Spring Teacher Conference, each teacher will create either a poster or a Powerpoint presentation describing their implementation experience. In addition, they will prepare an implementation report. The presentations and the reports will focus on describing what went well and not so well, what worked and what did not, and on reflecting on the attempt to teach for deep and enduring understanding.

ESBD makes two suggestions to facilitate the reflective process. One is to keep a self-reflective journal. The other is to exchange classroom visits with a partner teacher and to share that experience with each other in a structured way. These activities will help teachers grow as reflective practitioners and will make it easier to prepare the implementation report to share with colleagues.

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

2. Discuss the Partner Visit.

Briefly review the *Classroom Observation Guide*, the instructions for partners, the “running notes” and the completed examples, Handouts 17, 18, 19, and 20. Answer any questions the teachers may have. Remind teachers that they can get templates of these forms on the ESBD web site.

3. Discuss the purpose of journaling.

Start the discussion by brainstorming reasons for keeping a journal while teaching. Some participants may suggest record keeping. Others may view journaling as a planning tool. After teachers have offered several reasons, inform them that the primary goal of their ESBD journal will be to help them reflect on the process of developing and implementing an ESBD unit. Encourage teachers to consider their journals as their “thinking space.”

4. Review the *Journaling for Self-Reflection* Handout 15.

End the discussion by suggesting that teachers think of their journal as a place to record thoughts and insights that can feed into their implementation report.

5. Preview the Spring Teacher Conference documents.

Briefly preview the two documents: *Implementation Report Guide* Handout 21 and *Spring Conference Presentation Guide* Handout 22. Answer any questions.

HANDOUT 15**Journaling for Self-Reflection**

You have been asked to keep a journal of how your ESBD unit unfolds as you teach it. Writing down thoughts often helps to shape and clarify them. Keeping a journal of your teaching can encourage self-reflection, as well as provide a record of events as they occur. Try to capture your insights as best you can. Your journal is your own “thinking space.”

Journaling for description can be very useful, but potentially time consuming. Getting lost in the details can feel overwhelming and is one reason many teachers give up journaling. Provide the level of detail that you need to enable you to analyze and reflect on the teaching and learning process. More important than tracking events, is using a journal to track your thinking.

You may find it useful to organize your journal in a particular format or you may simply wish to write your thoughts in a freeform manner. Use sketches or graphic organizers if you like. Consider incorporating three aspects into your entries: 1) description, 2) analysis, and 3) reflection. The questions below are intended to guide, but not limit your journaling efforts.

Describe:

What happened during the lesson? What were you doing? What were the students doing? What do you remember most?

Analyze:

What worked? What didn't work? What evidence do you have that students either understood or misunderstood?

Reflect:

What does it mean? What ideas do you have about what you might do differently in the future? What insights do you have you about teaching and learning?

HANDOUT 16

Reflection Day Two

Name: _____ Date: _____

Do you feel prepared to implement your ESBD unit? Why or why not?

What part of the conference was the most useful to you?

Is there a topic that was not included in the conference that you would like to have seen addressed?

HANDOUT 17

Earth Science by Design Classroom Observation Guide

This guide is intended to structure the classroom observations that partners make of each other.

The purpose of the classroom observation is to provide feedback to your partner and to the Earth Science by Design project staff about what actually happened in the session. We believe that this feedback can help teachers improve their teaching. It also helps the project staff know how these sessions embody the principles of Understanding by Design.

The guide is organized in terms of questions about actual behavior. You should focus on directly observable behavior and should not include opinions or interpretations of the behavior. Please try to be objective!

Whenever possible, provide specific examples of the behavior you observed. Include as much detail as you can. (i.e. "Teacher asked for thumbs up/down signal three times and distributed a short written quiz at the end of the lesson.")

No one class session will include all the behaviors described below, so some questions will remain unanswered, or will simply be answered "no" or "not applicable."

Date _____ Approx. # of students in class _____

Teacher name _____

Observer name _____

Unit name _____

This session is # _____ of _____ sessions anticipated in this unit.

(Please attach any handouts students used in this session.)

Briefly describe the overall structure of this session:

The opening or introduction of the session:

The main activities of the session:

The closing or wrap-up of the session:

Describe Specific Teacher Behaviors Observed During this Session

Did the teacher introduce or review the essential questions of the unit? Describe.

Did the teacher make clear to the students how the activities of this session are related to the essential questions and the unit goals? Describe.

Did the teacher keep this session “on track” and aligned with unit goals, i.e. avoided “side trips” and tangential activities/discussions? Please describe.

HANDOUT 17 Earth Science by Design Classroom Observation Guide - Page 3

Did the teacher use informal methods to check for student understanding during the session? Please describe.

Did the teacher relate today's learning experiences to the culminating performance assessment? If so, please describe.

Did the teacher review or reinforce the expectations for the performance assessment?

Did the session include learning experiences that build the knowledge and skills that help students explore essential questions and big ideas? If so, describe the activities.

Did the teacher elicit student preconceptions or misconceptions and then use this information to guide the work of the session? If so, describe.

During this session, did students and/or the teacher use Web resources? Please describe.

Student Behaviors During this Session

Did students discuss or refer to the essential questions of the unit? If so, please describe.

Did students discuss or refer to the performance assessment? If so, please describe.

Did students relate today's learning experiences to the big ideas? If so, please describe.

Did students seem to be attentive and engaged in the lesson? Describe.

Did students ask questions or make statements that go beyond fact gathering and that reflect conceptual struggles? If so, please describe.

Did students demonstrate their understanding (i.e. "I get it! Now I know what you mean by the rock cycle, etc.")? If so, please describe.

Day 2

HANDOUT 17 Earth Science by Design Classroom Observation Guide - Page 5

In this session, were students asked to reflect upon and review essential questions? If so, how was this structured?

Were the students encouraged to monitor their own progress and learning? If so, please describe.

Reflections on the Session by the Partners

After this session, discuss your observations of this session with your partner. Encourage your partner to interpret and reflect upon their actions. Use this space to record your joint reflections about the session.

Reflection questions:

1. Did the session fulfill the goals the teacher had for it?
2. How could the session have been improved?

HANDOUT 18

Earth Science by Design Classroom Observation Guide – Instructions for Partners

The classroom observation guide is intended to structure the classroom observations that partners make of each other. The purpose of the classroom observation is to provide feedback to your partner and to the Earth Science by Design project staff about what actually happened in the session. We believe that this feedback can help teachers improve their teaching. It also helps the project staff know how these sessions embody the principles of Understanding by Design.

The guide is organized in terms of questions about actual behavior. The observer should focus on directly observable behavior and should not include opinions or interpretations of the behavior. Please try to be objective!

Whenever possible, provide specific examples of behavior you observed. Include as much detail as you can. (i.e. “Teacher asked for thumbs up/down signal three times and distributed a short written quiz at the end of the lesson.”) No one class session will include all the behaviors described below, so some questions will remain unanswered, or will simply be answered “no” or “not applicable.”

We recommend that you read over the guide to familiarize yourself with the questions before doing the observation but that you do not use the guide itself during the observation. Instead, focus on what is happening, and take “running notes” of the session as it unfolds. The questions in the guide will help you know what to focus on. For example, watch for the teacher’s use of “informal checks for understanding,” listen for discussion of the essential questions and references to the performance assessment, and observe student behavior. Use your “running notes” to fill out the guide afterwards.

After the session, schedule a time to sit down with your partner and discuss the session. (It would be ideal if there is a teacher planning period you could use for this purpose.) Go over the notes and the guide to make sure you both agree on what was observed. Use the reflective questions to help write up your reflections on the session.

Make 2 copies of the observation guide and of any handouts used by students during this session. Keep one copy for yourself and give one copy to your partner.

HANDOUT 19

Earth Science by Design - Example of "Running Notes" of a Classroom Session

Here is an example of the kinds of notes you might take in a classroom. From these notes you can then fill out the *Classroom Observation Guide*.

The Context of this Class Session (from prior discussion with the teacher and from reviewing the unit planner)

This class session is part of an introductory unit, *Journey to Planet Earth*. The unit presents Earth science as a voyage of discovery aimed at understanding the planet on which we live. It introduces the Earth system, and the major features of Earth's surface through remote sensing. Students acquire modeling and mapping skills as well as begin to build understanding of the methods of scientific inquiry.

A View from the Classroom

A remote sensed image of Buenos Aires is displayed onscreen to students as class begins.

The following questions and directions are posted, "Where on Earth do you think this image is from? What do you think the image shows? Write down your thoughts on a paper and discuss them with your team." Mrs. X takes a minute to take roll and organize paperwork.

Mrs. X points to the image. "Raise your hands and indicate with your thumb how confident you feel about what you wrote. OK. We will return to this image at the end of class."

"Remember that one of the BIG goals in this course is to use images of Earth from space to help us better understand our planet. We want to think of images as data that we can analyze and interpret, just like we do a table or a graph."

"Let's take a look at our essential questions for this unit." Mrs. X. points to the bulletin board. "Today we will focus on the second one,

How do images, maps, and models help us understand the Earth system?"

"As we continue on our journey to Planet Earth, let's examine some remote sensed images of Earth. Today, we will learn to recognize common features, such as roads, rivers, trees, irrigated fields, airports, and the like, as seen from the air. We will also ask questions about why things are where they are. Why is an airport located in one area and not another?" While talking, Mrs. X is advancing frames of a slide show depicting ground-based views of these features. "When your team plans its expedition to your chosen volcano, fault or other unique place, you will need to gather and interpret at least three images or maps. You will need to ask questions about what you see. What we learn today will help you with that part of your final project. Even if your team is planning a trip to the bottom of the ocean, as part of the voting public, you will need to be able to recognize the features we study today when you listen to the presentations from other teams. This will enable you to make an informed decision about whose proposed project should receive funds for further research."

HANDOUT 19 Earth Science by Design - Example of "Running Notes" of a Classroom Session - Page 2

"Think about what you learned about remote sensing yesterday. Remember that a variety of satellites operate and that each specializes in collecting a specific type of data. Recall and write down one type of information that we collect from these satellites."

Mrs. X then calls on various students.

i.e. "Sarah, would you please share what you wrote? "

Students respond with, "sea surface temperature, movement of storm systems, land temperature, etc." When a student response was incomplete she asked, "Would you explain what you mean?" When he was still unsure, she asked if he needed help and then called upon another student to help him.

"In addition to satellites, space shuttles and planes fly over Earth and take pictures. Today, we will explore some of these more detailed, small-scale images."

Mrs. X. stops talking and distributes papers to the groups. "This is a table of image features." Mrs. X holds up the table and points to it. "Here is a reference set of images." Mrs. X holds up two of the images from the reference set. "It is your goal to make sure that you and your teammates can identify these features in any remote sensed image. As you work through the questions, (Mrs. X. holds up the question sheet) make sure all of your team members are in agreement. There are two parts to the activity. One part uses the printed image set at your desks. The other part uses the computer stations. The class will be split in half. You will have 10 minutes for each part. Teams 1 to 4 will start at the computers. Teams 5 to 8 will remain at the desks. In ten minutes we will switch. After that, you will have 10 minutes to quiz each other on image features." Mrs. X. has eight groups of four students in this class. She has four computer stations and uses a split class structure. Half of the teams work with the printed images. The other half works at the computer. They switch places after 10 minutes.

Mrs. X. circulates among the teams as they work through the activity, Finding Features.

Students discussed their responses to the question sheet items. In particular, students are overheard discussing these two questions:

Write down something your team cannot identify on at least one of the images.

Write three questions raised by the image.

Activity: Quiz your teammates. Many students turn this activity into a game, pretending they are contestants and game show hosts.

Mrs. X flips the light switch three times. "OK. May I have everyone's attention? Tomorrow we will share and discuss the questions that today's images raised for your team. We will consider how these images show evidence of Earth's systems." Mrs. X points to the image of Buenos Aires, now displayed again at the front of the room. "For now, I'd like for us to return to the image with which we started. Take a minute

and look over what you wrote at the beginning of class. Go ahead and make any changes you'd like or add to what you wrote." Mrs. X. *pauses for a couple minutes, checking to see if students are finished writing.*

"Now, raise your hands and indicate with your thumb how confident you feel about what you have now written. "

Mrs. X points to features and asks for volunteers to identify them. After discussing features she asks if anyone thinks they know where on Earth this image is located. Since no one correctly identifies where the image is from, Mrs. X. informs the students of the location of the image. She puts it into a larger geographic context by having students open their texts and find Buenos Aires on a world map.

"What do you wonder about when you look at this image? Think of at least one "I wonder..." statement that this image brings to mind. Share this and any others with your teammates. "

Student responses include, "I wonder what the climate is like for the people who live there and I wonder where the river sediments come from." Noticeably absent are statements like, "I wonder why we have to know this?"

"Recorders, please hand in a list of at least four statements for the team, along with the question sheet for the activity. " Materials specialists from Teams 2 & 6, please collect all the papers." *Recorders hold up a stack of paper for the two team specialists that move from group to group collecting papers. These two students then hand the papers to Mrs. X.*

HANDOUT 20

Earth Science by Design Classroom Observation Guide: Completed Sample

This guide is intended to structure the classroom observations that partners make of each other.

The purpose of the classroom observation is to provide feedback to your partner and to the Earth Science by Design project staff about what actually happened in the session. We believe that this feedback can help teachers improve their teaching. It also helps the project staff know how these sessions embody the principles of Understanding by Design.

The guide is organized in terms of questions about actual behavior. You should focus on directly observable behavior and should not include opinions or interpretations of the behavior. Please try to be objective!

Whenever possible, provide specific examples of the behavior you observed. Include as much detail as you can. (i.e. "Teacher asked for thumbs up/down signal three times and distributed a short written quiz at the end of the lesson.")

No one class session will include all the behaviors described below, so some questions will remain unanswered, or will simply be answered "no" or "not applicable."

Date Approx. September 20, 2006 Approx. # of students in class 25

Teacher name Mrs. X.

School name School Circle Middle School

Observer name Observer Y.

Unit name Journey to Planet Earth

This session is # 5 of 16 sessions anticipated in this unit.

(Please attach any handouts students used in this session.)

Briefly describe the overall structure of this session:

The opening or introduction of the session:

At the beginning of class, Mrs. X displays an image of Buenos Aires, along with questions for students to answer. The following text is posted, "'Where on Earth do you think this image is from? What do you think the image shows? Write down your thoughts on a paper and discuss them with your team.'" She reminds students of an overarching understanding and an essential unit question that will be the focus of today's session. Mrs. X. tells students that today they will learn to recognize features in remote sensed images as well as ask questions about them. Mrs. X informs students how today's session relates to the final project. She helps them to recall the key concept of the previous session.

The main activities of the session:

Students are given a reference set of images with key features identified. Students examine printed images and a selected set of images on the Internet. They share and discuss ideas with team members as they complete a question sheet. The question sheet probes not only their ability to recognize features but also guides them to analyze images for geographic clues and evidence of Earth's systems. Students quiz each other on image features.

The closing or wrap-up of the session:

At the end of class, students return to the Buenos Aires image and identify features in the image. Mrs. X informs the students of the location of the image and puts it into a larger geographic context with a map presentation. Students write, "I wonder..." statements, share them with teammates, and turn them into Mrs. X, along with the question sheets from their activities.

Describe Specific Teacher Behaviors Observed During this Session

Did the teacher introduce or review the essential questions of the unit? Describe.

Yes. Mrs. X. both stated the question and pointed to it on the bulletin board. She said, "Let's take a look at our essential questions for this unit, "Today we will focus on the second one, How do images, maps, and models help us understand the Earth system?"

Did the teacher make clear to the students how the activities of this session are related to the essential questions and the unit goals? Describe.

Yes, indirectly. Mrs. X. used the expected outcome of the final project to connect today's activities with an essential unit question.

HANDOUT 20 Earth Science by Design Classroom Observation Guide: Completed Sample - Page 3

Did the teacher keep this session “on track” and aligned with unit goals, i.e. avoided “side trips” and tangential activities/discussions? Please describe.

Yes. When team 3 was exploring their image set, they noticed a storm and asked, “How do hurricanes begin?” Students began debating the issue among themselves. Mrs. X. intervened, suggesting they write down the question in the appropriate place on the question sheet. She assured them that they would have a chance to reconsider it later.

Did the teacher use informal methods to check for student understanding during the session? Please describe.

Yes. Mrs. X asked for a thumbs up/down signal at the beginning and at the end of class. She called on students to orally share their recollections of the types of information gathered by satellites. She instructed students to quiz their teammates on image features. She circulated among the teams while they were exploring and analyzing images, providing feedback as needed.

Did the teacher relate today’s learning experiences to the culminating performance assessment? If so, please describe.

Yes. In Mrs. X’s words, “When your team plans its expedition to your chosen volcano, fault or other unique place, you will need to gather and interpret at least three images or maps. You will need to ask questions about what you see. What we learn today will help you with that part of your final project. Even if your team is planning a trip to the bottom of the ocean, as part of the voting public, you will need to be able to recognize these features when you listen to the presentations from other teams. This will enable you to make an informed decision about whose proposed project should receive funds for further research.”

Did the teacher review or reinforce the expectations for the performance assessment?

Perhaps. When Mrs. X mentioned that all students would need to be able to identify features, she reminded them that they would be evaluating presentations made by other teams and that they would need to be prepared.

Did the session include learning experiences that build the knowledge and skills that help students explore essential questions and big ideas? If so, describe the activities.

Yes. Students analyzed remote sensed images with the goal of not only identifying features but also of asking questions and gathering evidence of Earth system processes.

Did the teacher elicit student preconceptions or misconceptions and then use this information to guide the work of the session? If so, describe.

Not observed. See discussion below.

During this session, did students and/or the teacher use Web resources? Please describe.

Students used EarthKam images and a NASA Earth from Space dataset during the computer portion of the activity. The volume of these datasets provides a comprehensive resource that lets students explore all over planet Earth. Both Web sites use map interfaces to geographically orient students to the images.

Student Behaviors During this Session

Did students discuss or refer to the essential questions of the unit? If so, please describe.

The majority of students glanced at the essential questions when Mrs. X. pointed to them on the bulletin board.

Did students discuss or refer to the performance assessment? If so, please describe.

A member of team 5 said, "I wonder what kind of vegetation we'll find around our volcano."

Did students relate today's learning experiences to the big ideas? If so, please describe.

Not observed.

Did students seem to be attentive and engaged in the lesson? Describe.

For the most part, students talked to each other about the images they were directed to analyze. Some students were quite animated when quizzing each other. Many teams used a game structure for the quizzing. Some team members spent time socializing. However, all completed the assigned tasks. When students were asked to give a show of hands or thumbs/up down signals, all of them participated.

Did students ask questions or make statements that go beyond fact gathering and that reflect conceptual struggles? If so, please describe.

Not observed. The discussion students had about their images were mostly focused on issues of orientation, geography and identification of features. The questions students turned in on their question sheet may reveal some of these.

HANDOUT 20 Earth Science by Design Classroom Observation Guide: Completed Sample - Page 5

Did students demonstrate their understanding (i.e. "I get it! Now I know what you mean by the rock cycle, etc.")? If so, please describe.

Students demonstrated their ability to recognize features. During today's session, they demonstrated their understanding through only one of the facets, the facet of self-knowledge. As they quizzed each other, students made comments like, "I think I can pick these out on other images." Many students nodded their agreement as students identified features on the Buenos Aires image.

Reminder of the facets for later discussion (explanation, interpretation, application, perspective, empathy, self-knowledge)

In this session, were students asked to reflect upon and review essential questions? If so, how was this structured?

They did not review the essential question but did review the main goal of the lesson.

Were the students encouraged to monitor their own progress and learning? If so, please describe.

Students monitored progress within their teams when they quizzed each other.

Reflections on the Session by the Partners

After this session, discuss your observations of this session with your partner. Encourage your partner to interpret and reflect upon their actions. Use this space to record your joint reflections about the session.

Reflection questions:

1. Did the session fulfill the goals the teacher had for it?
2. How could the session have been improved?

When discussing the session, Mrs. X related that she had four goals for the lesson. She hoped students would ...

- 1) understand that images are data that can be analyzed.
- 2) be able to recognize common features they might encounter in remotely sensed images.
- 3) become familiar with basic geography of the Earth (i.e. location of continents, and major countries).
- 4) ask questions as an attempt to begin to interpret remotely sensed images.

She did not have enough time to go into depth on goal 4 with students. However, she discussed her intention to guide student questioning to a deeper level where questions focus on the Earth systems. The questions raised by students along with further analysis of images will be the focus of the next session.

In a prior class Mrs. X had elicited preconceptions and misconceptions by showing an image and asking students, "Tell me everything you think you know about this image." She thinks that she may be able to document more misconceptions in tomorrow's session as students begin to interpret why features are where they are."

HANDOUT 21

Implementation Report Guide

For the Spring Conference, each ESBD teacher should prepare a report on the implementation of the unit they created. The implementation report is a way to share your ESBD implementation experience with colleagues. The report should highlight the unit you created and summarize your experience implementing ESBD.

One way to help you get ready for the writing this report is to keep a journal of ESBD related matters, such as thoughts on planning, observations about student learning and reflections that come to you while teaching your unit. You might consider taking notes on your implementation experience organized according to the sections of the report described below.

1. Describing Your ESBD Unit

- Begin with a brief overview of your unit.
- Attach a copy of your Unit Plan to the Implementation Report. This should be the unit as you planned to implement it. Include a printed version of your unit, your rubric, and your pre- and post-assessment quizzes as appendices to your report.
- Attach a copy of your revised Unit Plan. This plan should reflect the sequence of activities that took place during implementation. Include any handouts you created or used during the unit. If you have a lot of materials, you may want to organize them in a three-ring binder.

2. Uncovering Misconceptions

- What misconceptions did you uncover during your unit? Were any of these surprising?
- How successful do you feel you were at addressing these? What might you do differently next time?

3. Building Understanding

- Describe a few strategies you used to help students uncover and build their understanding of your unit concepts.
- Which of the facets of understanding did your unit emphasize? Cite a few examples.
- Describe an activity that you feel really got at deep and enduring understanding.
- Comment particularly on any use of visualizations. How effective were they in helping students achieve understanding? What difficulties, if any, did you encounter in using them?
- What might you do differently in the future?

4. Assessing Student Learning

- Describe the evidence you collected and used to “convict” your students of understanding.
- What was most effective in helping you and them assess their understanding?
- Do you feel your students really developed deep and enduring understanding of your unit concepts?
- Use specific work produced by your students during the unit to illustrate your points.

5. Reflecting on the Implementation Process

- In addition to describing the unfolding of your unit in your classroom, the report is intended to serve as a reflective space for you to share your thoughts about the implementation process. What insights or new understandings have you gained from this experience?
- How have you grown as a teacher?
- How was the experience of doing this ESBD unit different from other Earth science units you have done in the past?
- What issues or questions has ESBD raised for you?
- What advice or guidance might you offer others interested in ESBD?

Please feel free to contact any of the ESBD staff if you need clarification or have any questions.

HANDOUT 22

Spring Conference Presentation Guide

At the Spring Conference we want you to make a brief presentation sharing the results of your implementation of your ESBD unit. Consider this presentation to be along the lines of one you might give at a professional conference. We encourage you to create a tri-fold poster, similar to the sort your students might produce for a science fair. However, you may choose to prepare a PowerPoint presentation in addition to, or instead of, the poster. Your presentation should briefly summarize key aspects of the implementation report. We will have two formats for sharing at the conference; large group presentations and poster breakout sessions. Plan on having about 10 minutes to make your presentation.

Please be sure your poster or PowerPoint includes the following items. (Many of them can just be copied from your Unit Planner.)

- A brief description of the unit
- The unit enduring understandings
- The unit essential questions
- A brief description of the performance assessment
- A description of the evidence that you used to assess student understanding (plus representative student work, if possible)
- Insights you gained or new understandings that you have from implementing ESBD
- Issues or questions that the implementation process raised for you
- Photos of students engaged in the activities of your unit and/or other supporting visuals

Please feel free to contact any of the ESBD staff if you need clarification or have any questions.

APPENDIX A

September 1, 2006

Dear ESD Teacher,

I hope your return to school is going well and that you are excited by the new year ahead of you! In a few weeks we get together for the ESD Fall Conference at XXX. This letter and the enclosed materials will help you get ready. We are really looking forward to seeing you again and catching up on how things are going. I think we have planned a stimulating and invigorating conference. I've enclosed the draft agenda.

I've also enclosed a letter to your principal expressing thanks for their support and urging them to support you in attending the conferences and throughout the year. Please give it to your principal along with a copy of the draft agenda.

At the conference we will

- Deepen our understanding of ESD and UBD
- Think about how students learn and how we assess that learning
- Share our preconception assessments and how we will use that information to improve our teaching
- Discuss how an Earth systems approach can enrich a unit
- Share and discuss great visualization resources
- Share and discuss our rubrics
- Meet with mentors and partners to review the units and plan improvements
- Prepare a plan for implementing ESD in your classrooms

Here is what you need to do to prepare for the conference:

- We begin Thursday morning with a discussion of "how people learn." Our discussion will be based on *How People Learn: Bridging Research and Practice*, published by the National Academy Press. Read Chapter 2 of the book on the web at <http://books.nap.edu/html/howpeople2/ch2.html>. Come prepared to discuss the questions on the reflection sheet enclosed with this letter. We will break into small groups and your group will be given one of the questions to discuss.
- Later Thursday morning we will discuss our preconception assessments, so bring 5 copies of your assessment to share.
- Also on Thursday morning we will discuss some selected ideas from *Dr. Art's Guide to Planet Earth*, so bring your copy of the book. It would be good to re-familiarize yourself with the ideas in it, too.

APPENDIX A

- Thursday afternoon you will have time to meet with your mentor and partner to discuss your unit and to plan revisions. We will download and print copies of everyone's unit on Tuesday, so try to complete any changes you want to make before that time.
- Thursday afternoon in the Visualization Roundtable we will share visualizations we have found that help teach important ideas in our units, so bring the URL for one that you want to share and discuss. Refer to the enclosed *Visualization Sharing Guidelines*.
- Friday morning in the Rubric Roundtable we will break into small groups and discuss the rubrics you have created for your performance assessments, so bring 5 copies of your rubric.

Call me at XXX if you have any questions about the conference.

Looking forward to seeing you,

XXX

Site Leader

Enclosures

- ☐ Discussion Questions for Chapter 2 of *How People Learn: Bridging Research and Practice*
- ☐ *Visualization Sharing Guidelines*
- ☐ Letter to principal

Spring Conference

SPRING

Table of Contents

Overview	2
Day 1 and 2 Overview and 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

Spring Conference

SPRING

Overview

The Spring Conference provides teachers with the opportunity to share the results of implementing their ESBD Units in their classrooms. Teachers present their units and highlight their implementation experiences through poster sessions and/or Power-Point presentations that are along the lines of the sort they might give at a professional conference. In a series of breakout sessions, teachers discuss their findings, raise questions, and offer insights about how the ESBD program has changed their classroom practice and affected their ideas about teaching and learning. The major topics of the breakout sessions parallel the implementation report they prepared, allowing teachers to thoughtfully discuss issues with colleagues. Toward the end of the conference, teachers make plans for their continued professional growth by considering research-based approaches that they might want to learn more about. Teachers leave with copies of each other's ESBD unit plans and with ideas for how they might improve their existing units and/or craft new ones for the following year.

Goals

Attending the Spring Conference will help teachers to:

- Reflect and discuss their ESBD implementation experience with like-minded colleagues
- Consider new assessment strategies and new ways to help students build understanding as they strive to reduce misconceptions
- Gain ideas for future ESBD unit development

Conference Leaders Do Ahead:

- ☐ Send an invitation to the conference by regular or email. A sample invitation is included in the Appendix. Consider sending a copy of *Misconceptions in Earth Science: Uncovering and Changing Students' Naive Ideas*, found in Appendix B of the Summer Institute Handbook, or directing teachers to the ESBD web site. See Activity 6 where this is used.
- ☐ Remind teachers to complete any final revisions to their unit plans at least a few days before the conference so the units can be printed and distributed at the conference.
- ☐ Prepare a Conference Notebook for each participant. Include in it:
 - The conference agenda
 - Photocopy of the ESBD unit of each participant (rubrics should be included or teachers reminded to bring them)
 - Photocopy of all handouts. Access as PDFs on the ESBD web site.
- ☐ For the conference, secure a large room conducive to hosting Poster sessions. Teachers will need to be able to move freely about the room and easily view posters during the session.
- ☐ Invite three teachers to share findings from their analysis of their students' pre and post conception surveys. (Refer to Activity 2 for further details).

Spring Conference

SPRING

- ☐ Post the ESBD Program Essential Questions in the main meeting room of the conference and refer to them periodically throughout the two days.
- ☐ Arrange for Internet connection and a computer projector system.
- ☐ Obtain a video camera to record part of Activity 8 (optional).
- ☐ Preview Activity 4. (You may want to gather and share samples of student work or journal articles.)
- ☐ Preview Activity 7 and arrange for panelists.

Note: The time estimates in the conference activities are based on twenty teachers participating. Presentations and discussion sessions will take considerably less time with fewer teachers.

Introducing the Spring Conference

The Spring conference is the culmination of the ESBD professional development program. However, it is hoped that it is the beginning of an ESBD journey that will last teachers several years. This is a good time to bring teachers back to the original ESBD program Essential Questions. (Questions that can be enlarged and displayed are found as PDFs on the ESBD web site.) Refer to and incorporate these questions as they pertain to individual activities. The following list indicates the activities that address these questions:

1. How do we teach for *understanding* in Earth system science?
Activity 1
2. How do we design appropriate *assessments* to evaluate understanding in Earth system science?
Activity 2, Activity 3, Activity 4
3. How do we move students from their strongly held *misconceptions* toward more enduring understandings in Earth system science?
Activity 6
4. How do we use scientific *visualizations* to build understanding in Earth system science?
Activity 1
5. How do we use *reflection* to understand and improve teaching?
Activity 8
6. What are the characteristics of an *Earth Science by Design* teacher?
Activity 5, Activity 7

Spring Conference

DAY 1

SPRING CONFERENCE

Day 1 Overview

Digging into student understanding is the focus of this day. Teachers discuss strategies and approaches for building, assessing, and analyzing understanding. During separate twenty-minute time slots, three teachers share results of analyzing student pre and post conception surveys. Half of the teachers make poster and/or PowerPoint presentations on Day 1.

During the introduction, review the ESBD Essential Questions, which you have posted in the meeting room and point out that the conference activities address all of these issues.

Day 1 Schedule

8:00-8:45	Set up of posters
8:45-9:00	Welcome and Introduction
9:00-9:45	Building Enduring Understanding in Your Classroom
9:45-10:00	Reports from Small Groups
10:00-10:15	Break
10:15-10:35	Analyzing Understanding: Evidence from Pre and Post Conception Surveys; Case 1
10:35-11:15	Assessing Student Learning in ESBD
11:15-11:30	Reports from Small Groups
11:30-12:00	Teaching Methods that Reveal Student Thinking
12:00-1:00	Lunch
1:00-1:20	Analyzing Understanding: Evidence from Pre and Post Conception Surveys; Case 2
1:20-2:35	Sharing Implementation Results: Poster Sessions & PowerPoint presentations by teachers (first group)
2:35-2:55	Break
2:55-3:15	Analyzing Understanding: Evidence from Pre and Post Conception Surveys; Case 3
3:15-3:30	Online Reflection
3:30	Adjourn

Spring Conference

DAY 2

SPRING CONFERENCE

Day 2 Overview

Change and growth are key themes on Day 2. Teachers discuss ways to confront and gradually alter misconceptions. They consider research-based professional growth opportunities in science education and they discuss how ESBD has affected their teaching practice. Once again, time is set aside for half of the teachers to make poster and/or PowerPoint presentations.

Day 2 Schedule

8:00-8:45	Set up of posters
8:45-9:00	Welcome and Introduction
9:00-9:45	From Misconceptions to Enduring Understanding
9:45-10:00	Reports from Small Groups
10:00-10:15	Break
10:15-11:15	ESBD & Research-Based Practice
11:15-12:30	Sharing Implementation Results: Poster Sessions & PowerPoint presentations by teachers (second group)
12:30-1:30	Lunch
1:30-2:30	How ESBD Has Affected Me as a Teacher and a Learner
2:30-3:30	Sharing by Individuals and Congratulations to ESBD graduates
3:30	Adjourn

ACTIVITY 1

Building Enduring Understanding in Your Classroom

Description

In this activity, teachers first work in small groups to identify and share activities from Stage 3 of their ESBD unit that helped move their students towards deep and enduring understanding of the unit's essential questions. Second, they share a particularly effective visualization or Internet resource they applied in their Stage 3 activities. Last, they try to identify the common characteristics of the successful activities and visualizations that make them effective in promoting deep and enduring understanding. In a final whole-group discussion, each group shares its thoughts about the common characteristics that make certain activities and visualizations effective in moving students towards more enduring understanding.

Goals

Completing this activity will help teachers to:

- Review strategies to achieve deep and enduring understanding of Earth science concepts.
- Identify outstanding visualizations and Internet resources that help students achieve a deeper and more enduring understanding of unit concepts.
- Derive the characteristics of activities and visualizations that are effective in promoting deep and enduring student understanding.

Materials

- ☐ Individual ESBD Unit plans
- ☐ *Discussion Questions for Building Enduring Understanding in Your Classroom* Handout 1

Approximate Time

60 minutes

Procedure

1. **Conduct an introductory large group discussion about the teaching strategies that teachers used to promote deep and enduring understanding.** Begin with this question to participants: "As you implemented your unit, what approaches did you use to promote deep and enduring understanding? Do not describe specific learning activities as you will be discussing these in a few minutes." Allow 5 minutes for a general discussion. Teachers might mention strategies such as posting essential questions, using performance assessments, using hook activities, or engaging students in inquiry labs.
2. **Divide participants into small groups to share the Stage 3 activities and visualizations they feel were most effective in achieving deep and enduring understanding for students.**

ACTIVITY 1 Building Enduring Understanding in Your Classroom - Page 2

3. **Provide one staff facilitator for each group to serve as a moderator.** Make sure someone other than the facilitator is either selected or appointed as the reporter for each group. The facilitator should not be the reporter because his or her job is to guide the discussion. Seat participants in a circle if possible. Check to see that every group member gets a chance to share his or her thoughts. Moderators should not hesitate to make sure everyone is brief and to the point, allowing time for others to talk.
4. **Refer teachers to *Discussion Questions Handout 1*.** Allow teachers about 5 minutes to fill in some notes about the information they want to share. They may want to refer to their individual ESD Unit plans as well.
5. **Facilitate a discussion in which each teacher briefly explains the activity they selected in response to Question 1.** The Recorder should take notes on the discussion and be prepared to report back to the whole group later.
6. **Facilitate similar discussions centered on Questions 2 & 3.** Allow approximately 15 minutes discussion time per question.
7. **Reconvene as a whole group and have the reporter relate their group's discussion of Question 3.** What did they identify as the characteristics of successful activities and visualizations that made them so effective in moving students towards deep and enduring understandings?
8. **Facilitate a whole-group discussion of what these characteristics seem to be and the implications for future unit development and teaching.** Record the group's ideas on poster paper for possible later consideration.

Discussion Questions for Building Enduring Understanding in Your Classroom

1. Describe one activity that you feel really helped move students towards a deep and enduring understanding of the concepts in your unit. Indicate which Enduring Understanding or Essential Question this activity helped students understand.
2. Describe a visualization or Internet resource that you thought helped students achieve a deeper understanding of one of your concepts. Indicate which Enduring Understanding, Essential Question, or skill this activity helped students understand.
3. Thinking about the activities and visualizations that the group has identified, what characteristics make them so effective in promoting deep and enduring understanding?

ACTIVITY 2

Analyzing Understanding: Evidence from Pre and Post Conception Surveys

Description

In this activity, three teachers present the results of analyzing their pre and post conception surveys. They describe patterns, themes, and models of student thinking exhibited in the surveys. They answer questions and discuss surprising findings with other participants.

Goals

Completing this activity will help teachers to:

- Analyze pre and post conception surveys
- Make data-driven instructional decisions

Materials

- ☐ *Guiding Questions for Presentations on Student Understanding Handout 2*
- ☐ Copies of the three teachers' pre and post conception surveys

Approximate Time

Three 20-minute sessions

Procedure

- 1. Prior to the conference, invite three teachers to share findings from their analysis of their students' pre and post conception surveys.**
Tell them that they will have about 10 to 15 minutes to share their results and another 5 to 10 minutes to answer questions and discuss findings with other teachers. (The total presentation time is limited to 20 minutes.)

For guidance and as an example, refer teachers back to slides 25 through 39 of *Tapping Into Preconceptions* (Activity 2 from the Fall Conference). Also, to help them prepare, give them each a copy of Handout 2.
- 2. Facilitate the presentations by keeping track of the time and moderating questions.**
- 3. Highlight key points of each presentation and emphasize the importance of collecting pre and post conception survey data for several years.** At the close of the third session, briefly highlight the findings from all three presentations. Suggest that in order to get a sense of the most commonly occurring themes and models, they consider collecting and aggregating the data from students' Pre and Post Conception Surveys for several years.

Point out to teachers that the data they collect on student pre and post conception surveys can form the basis for presentations they might make at professional conferences. They are a way of presenting evidence for the effectiveness of the ESBD approach.

HANDOUT 2

Guiding Questions for Presentations on Student Understanding

Prepare a 10 to 15 minute presentation that describes the results of your pre and post conception surveys. (20 minutes have been set aside but save 5 minutes for questions and discussion.) You may create a PowerPoint presentation or use overheads. Briefly describe the items on your survey and bring copies of it to share. Analyze your survey data and present key findings. As an example, you may wish to refer back to slides 25 through 39 of Tapping Into Preconceptions (Activity 2 from the Fall Conference). Use the following questions to help guide your presentation.

1. What patterns or themes are evident in the preconception surveys? What models do students hold? Are the ideas revealed here surprising? Can you trace their thinking back to where their ideas may have originated?

2. How do these notions or ideas compare to those exhibited in the post-conception surveys?

3. How did you use the results of the preconception survey to plan or modify your Stage 3 activities in your ESBD unit?

ACTIVITY 3

Assessing Student Learning in ESBD

Description

In this activity, teachers work in small groups and discuss whether their Stage 2 performance assessments were effective in convicting students of understanding. Second, teachers examine their pre and post conception quiz results and discuss how these results will inform their future Stage 3 activity sequence and organization. Last, teachers consider what features or aspects of these assessments were most effective in moving students towards deep and enduring understanding.

Goals

Completing this activity will help teachers to:

- Review other teachers' performance assessments and rubrics.
- Reflect on what characteristics of ESBD assessments are most effective in moving students towards deep and enduring understanding

Materials

- ☐ Copies of All Teachers' ESBD Unit plans
- ☐ *Discussion Questions Handout 3*

Approximate Time

55 minutes

Procedure

1. **Divide participants into small groups to share their Stage 2 performance assessments and rubrics.**
2. **Provide one staff facilitator for each group to serve as a moderator.**
Make sure someone other than the facilitator is either selected or appointed as the reporter for each group. The facilitator should not be the reporter because his or her job is to guide the discussion. Seat participants in a circle if possible. Check to see that every group member gets a chance to share his or her thoughts. Moderators should not hesitate to make sure everyone is brief and to the point, allowing time for others to talk.
3. **Refer teachers to *Discussion Questions Handout 3*.**
Allow teachers about 5 minutes to fill in some notes about the information they want to share.
4. **Each group moderator should facilitate a discussion in which each teacher briefly discusses their response to Questions 1 and 2.**
The Recorder should take notes on the discussion and be prepared to report back to the whole group later.
5. **Reconvene as a whole group and have the group reporter relate their group's discussion of both questions.**
6. **Facilitate a whole-group discussion of what these features or aspects seem to be and the implications for future unit development and teaching.**
Record the group's ideas on poster paper for possible later consideration.

HANDOUT 3**Discussion Questions for Assessing Student Learning in ESD**

In small groups, discuss these questions:

1. How effective was your performance assessment in
 - a. allowing you to assess your students' understanding?
 - b. allowing each student to demonstrate their understanding?
 - c. motivating them to learn?

2. What features or aspects of your performance assessment were most effective in moving students towards deep and enduring understanding? Which facets of understanding came into play in your performance assessment?

ACTIVITY 4

Teaching Methods that Reveal Student Thinking

Description

In this activity, participants discuss teaching methods that help to reveal student thinking. In previous years, ESBD teachers have used concept mapping and journaling as strategies for uncovering student understanding.

Goals

Completing this activity will help teachers to:

- Consider adopting strategies that help them gain insights into their students' thinking

Materials

- ☐ Examples of a concept map, journal entry, diagram (Optional)

Approximate Time

30 minutes

Procedure

1. **Begin this whole group discussion by reminding participants that some types of assessments may more readily lead to “false positives”.**
Using a performance assessment helps to reduce the likelihood of both false positives and false negatives. However, it is also important to reveal student thinking throughout a unit of instruction. You may want to say something similar to the following:
“When all your students bubble in the correct answer to a multiple-choice question, you may feel with some degree of confidence that students obviously understand the underlying concepts. However, if you start to probe their thinking, you may find that they got the question right for all the wrong reasons. Their thinking may, in fact, be flawed, or heavily influenced by intuitive ideas. True understanding may be buried beneath the surface of what seems like a hardened crust of impermeable misconceptions. If we are to find out what our students really understand, then we may need to dig into their thinking. What methods have you used to help to reveal student thinking?”
2. **If teachers do not bring them up, suggest strategies such as concept mapping, journaling, and making diagrams of Earth system processes.**
Several visual tools can display the way students structure knowledge. These include concept maps, vee maps, and semantic networks. Some teachers may be familiar with concept mapping and will have used them in their ESBD unit. You may want to make an overhead of a student-generated concept map to show as an example. Another strategy that derives from these tools is visual thinking networking (VTN). It combines the branching of concept maps with pictorial and diagrammatic representations. In Earth science class, VTNs have been used by students to structure concepts and to reflect upon their understanding of how the concepts

ACTIVITY 4 Teaching Methods that Reveal Student Thinking - Page 2

relate to one another. VTNs can not only be used as tools for self-reflection, but also can demonstrate conceptual learning and the deep understanding of Earth systems processes.

- 3. Briefly discuss each strategy and encourage teachers to share how they used the strategy in their unit and what they were able to gather about student understanding by using the strategy.**

For example, one ESD teacher used concept mapping to review the main understandings in her earthquake unit. As students linked divergent and convergent boundaries with plate motions and associated tectonic activity, she could clearly see if students understood the dynamics of plate interactions. Looking across all the maps, she was able to see common gaps in their thinking, helping her to hone in on just those areas in which students were still struggling.

For additional background information about concept mapping and some example maps, visit <http://chd.gse.gmu.edu/immersion/knowledgebase/strategies/cognitivism/conceptmap.htm>

- 4. Facilitate the session by keeping track of the time and moderating questions so that one person does not dominate the discussion.**

At the end of the session, draw the discussion to a close by highlighting key points that were raised and encouraging teachers to use these strategies in future ESD teaching.

ACTIVITY 5

Sharing Implementation Results

Description

In this session, teachers make their conference presentations based on their classroom implementation of their ESBD units. They may have prepared either a poster or PowerPoint slides or both. Many will likely have brought a notebook containing samples of student work, other handouts they used during the unit, and their Implementation Report. A five to ten minute time limit is set for PowerPoint presentations. This session is modeled after the poster sessions and presentations that teachers give at professional conferences such as the National Science Teachers Association.

Goals

Completing this activity will help teachers to:

- Share their implementation experiences

Materials

- ☐ Large room for displaying posters
- ☐ Computer with projector and Internet access

Approximate Time

Two and a half hours split into two 75-minute sessions, one per day.
Note: This time estimate is based on 20 participating teachers. Adjust the time according to the number in your ESBD program.

Procedure

1. **Divide the teachers into two groups of approximately the same size: Group 1 and Group 2.**
 Group 1 will present on Day 1. Group 2 will present on Day 2.
2. **For each group, determine how many teachers have brought PowerPoint slides with them and allocate the first portion of each 75-minute session to these presentations.**
3. **Facilitate the presentations by keeping track of the time and moderating questions.**
 Limit each presenter to no more than 5 to 10 minutes each, including questions or comments from the audience.
4. **After the PowerPoint presentations are done each day, facilitate the poster session.**
 On Day 1, ask Group 1 teachers to stand by their posters, prepared to discuss their experiences and answer questions while Group 2 moves around the room, visiting posters. Teachers should switch positions on Day 2.
5. **Collect Implementation Reports at the end of each session.**
 At the close of each poster session, ask teachers to turn in a copy of their implementation reports. When preparing their reports, teachers should have followed the guidelines on Handout 21 of the Fall Teacher Conference Guide. Encourage teachers to consider making similar ESBD presentations at professional conferences they might attend in the future.

ACTIVITY 6

From Misconceptions to Enduring Understanding

Description

In this activity, teachers work in small groups and discuss the results of their pre and post conception surveys. Second, teachers list any new or unusual misconceptions they have uncovered in the teaching of their units. Lastly, teachers consider what strategies they used to change student misunderstanding to a deeper and enduring understanding of the concepts in their units.

Goals

Completing this activity will help teachers to:

- Assess the effectiveness of pre and post conception surveys
- Gain a broader view of the variety of misconceptions that exist in Earth systems science
- Review strategies for confronting and combatting misconceptions in Earth science

Materials

- ☐ *Discussion Questions for From Misconceptions to Enduring Understanding Handout 4*
- ☐ Copies of all teachers' units
- ☐ Examples of student's pre and post conception survey results (supplied by teachers)

Approximate Time

60 minutes.

Procedure

1. Hold a large group discussion to review what a misconception is and is not.

To prepare for this activity, re-read the essay *Misconceptions in Earth Science by Design: Uncovering and Changing Student's Naïve Ideas* in Appendix B of the Summer Institute Handbook. Consider copying the essay and sharing it with teachers before the conference.

Remind teachers that not knowing the meaning of a concept does not indicate that a student holds a misconception. Rather, a misconception occurs when a student interprets a process or concept incorrectly, forming a strongly held belief that is frequently difficult to dislodge. In the area of physics, misconceptions have been widely studied by science education researchers. Not as much research has been conducted in the Earth sciences. Remind teachers that data from their students' pre conception surveys gives them the opportunity to structure learning activities that help students build understanding in order to replace their current conceptions with more adequate ones.

Introduce (or review) the Model of Conceptual Change described in the essay on misconceptions. Discuss any questions about the nature of the model.

2. Divide participants into small groups to share their pre and post conception surveys and student results.

3. Provide one staff facilitator for each group to serve as a moderator.

Make sure someone other than the facilitator is either selected or appointed as the reporter for each group. The facilitator should not be the reporter because his or her job is to guide the discussion. Seat participants in a circle if possible. Check to see that every group member gets a chance to share his or her thoughts. Moderators should not hesitate to make sure everyone is brief and to the point, allowing time for others to talk.

4. Refer teachers to Discussion Questions Handout 4.

Give the teachers about 5 minutes to fill in some notes about the information they want to share.

5. Then facilitate a discussion in which each teacher briefly discusses their response to Question 1 and 2.

Elect or appoint a Recorder who will take notes on the discussion and report back to the whole group. Allow about 20 to 25 minutes for teachers to discuss each question.

6. Reconvene as a whole group and have the reporter relate their group's discussion of both questions.

Facilitate a whole-group discussion of misconception theory, the Model of Conceptual Change, and the strategies they used to move students away from misconceptions and toward more enduring understandings. Record the group's ideas on poster paper for possible later consideration.

Discussion Questions for From Misconceptions to Enduring Understanding

1. Describe any new or surprising misconceptions expressed by students as your unit progressed.
2. Describe specific strategies you used in your unit to move students from their strongly held beliefs toward more enduring understandings. For example, in accordance with the Model of Conceptual Change, how did you
 - a. raise student awareness of misconceptions?
 - b. help students confront their misconceptions?
 - c. help students resolve the differences between old and new understandings?
 - d. offer opportunities to extend and make connections between their understandings, other Earth science concepts, and their daily lives?

ACTIVITY 7

ESBD and Research-Based Practice

Description

Several areas of research-based practice are complementary to the *Earth Science by Design* program. These include inquiry learning, discrepant events, action research, technology-enhanced learning, and cooperative learning, among others. Reading about these approaches in journal articles or enrolling in university courses on these topics provides professional growth opportunities for science teachers. In this panel discussion, science teachers and staff development specialists are invited to share their expertise on a specific topic by providing a brief overview and pointing participants to resources that they can investigate later in order to learn more about the topic. The intention behind this session is to motivate teachers to continue their professional growth beyond the end of the ESBD program.

Goals

Completing this activity will help teachers to:

- Become aware of areas of research-based practice that they can learn about in order to improve their science teaching
- Become aware of the journals in which science educators and science teachers frequently publish

Materials

- ☐ Panelists willing to overview specific research-based practices (These need not be “guest” panelists, but could come from the staff team and the participants themselves)
- ☐ Copies of any handouts panelists may bring

Approximate Time

60 minutes (three or four 15 to 20 minute presentations and discussion)

Procedure

1. **Prior to the conference, arrange for panelists to overview a specific research-based practice applicable to science teaching.**
Tell them that they will have about 10 to 15 minutes for their presentation and 5 to 10 minutes for questions from participants. To help them prepare, refer them to Handout 5. Presentations may focus on inquiry learning, discrepant events, action research, technology-enhanced learning, and cooperative learning, or others relevant to your participants teaching settings. Increasing Earth science content knowledge (and ways to go about doing that) could also serve as one topic area for the panel discussion.
2. **Facilitate the presentations by keeping track of the time and moderating questions.**
3. **At the end, highlight key points of each presentation and emphasize the importance of keeping informed of current research in science education.**

ACTIVITY 8

How ESDB Has Affected Me as a Teacher and a Learner

Description

In this activity, teachers reflect individually and in groups on how the ESDB program has changed their classroom practice and their ideas about teaching and learning. They think about how the ESDB process has reshaped, expanded, and re-directed their approaches to teaching.

Goals

Completing this activity will help teachers to:

- Examine the impact that the ESDB process has had on their practice and philosophy of teaching and learning
- Share ideas about how the ESDB program has transformed their teaching practices

Materials

- ☐ *Discussion Question for How ESDB Has Affected Me as a Teacher and a Learner: Handout 6*
- ☐ Video camera to record teachers statements (optional)

Approximate Time

75 minutes

Procedure

1. Refer teachers to Handout 6 and ask them to work individually to answer the following question on the sheet:
 “Think back to how you approached teaching and learning before this workshop and how you approach it now. Describe how your current practice and philosophy of teaching and learning compares with one year ago. What aspects of the program did you do previously (if any)? What do you do differently as a result of the program? What is the most important change that has occurred through the ESDB process?”
2. Reconvene the whole group and ask teachers to individually share their responses to the question.
 If possible, record this discussion on video camera.

HANDOUT 6

Discussion Question for How ESBD has Affected Me as a Teacher and a Learner

1. Think back to how you approached teaching and learning before participating in ESBD and how you approach it now. Describe how your current practice and philosophy of teaching and learning compares with one year ago. What aspects of the program did you do previously? What do you do differently as a result of the program? What is the most important change that has occurred through the ESBD process?

APPENDIX A

January 25, 2007

Dear ESBD Teacher,

Your participation is requested at the **Earth Science by Design Conference** to be held on February 4 and 5, 2007 at TERC! The conference will begin at 8:00 with a continental breakfast and adjourn at 3:30 each day.

The conference will showcase each participant's unit and address a variety of topics involved in their completion. These include:

- Building Enduring Understanding in Your Classroom
- Analyzing Understanding: Evidence from Pre and Post Conception Surveys
- Assessing Student Learning in ESBD
- Teaching Methods that Reveal Student Thinking
- From Misconceptions to Enduring Understanding
- ESBD and Research-Based Practice
- How ESBD Has Affected Me as a Teacher and a Learner

Each of you will be asked to share your experience of implementing ESBD in small and large discussion groups as well as make a brief presentation highlighting student work and your personal experiences.

On February 2, around noon, we will print out and photocopy all the units as they are at that moment in the Unit Planner, so make any revisions you want before that.

One of the highlights of the conference will be each participant's *Conference Presentation*. This presentation can take the form of a tri-fold poster or a Power Point presentation or any format that will allow you to share the essence of your unit. You will find suggested components at the end of the *Implementation Report* guidelines. Please remember that these are guidelines and you may not feel that it is important to include each component in your presentation. Please also bring a copy of your *Implementation Report*. We have enclosed the guidelines for the report and presentation. They can also be downloaded from the ESBD website www.esbd.org

You need to log into the Community area to get to them. Contact your ESBD mentor if you want to discuss your preparation of the *Implementation Report* or the *Conference Presentation*.

Sincerely,