

The NSDL Strand Map Service: A Networked Knowledge Organization and Visualization System for K-12 Education



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Overview



- Background
 - National Science Digital Library
 - AAAS Benchmarks and Strand Maps
 - Task-centered design
- Brief look at the Strand Map Service
- Our design process and methodologies
- Conclusions
 - benefits of ‘good’ design practices & products
 - impact on our partners (DLESE & AAAS)

National Science Digital Library (NSDL)



- Systemic improvements in science, engineering, technology, and mathematics education, at all levels, in formal and informal settings
- Distributed network: 120+ projects funded by the National Science Foundation (collections, services, targeted research, core integration, libraries)
- K-12: challenge is to help students master (nationally-)recognized learning goals and help teachers create inquiry-oriented science learning experiences

AAAS Benchmarks and Strand Maps



- **AAAS and Project 2061:** long-term vision of empowering teachers and school districts to design coherent curriculum
- **Benchmarks:** describe what learners should know, or be able to do, at key stages in their education across the STEM disciplines
- **Strand maps:** consist of node-link representations illustrating how student understanding changes over time around topics important to science literacy
- **Our mission**
 - AAAS perspective - maps as interface to library
 - NSDL perspective - develop a means of making benchmarks and maps available within the NSDL network

What is a Benchmark?



3-5

When warmer things are put with cooler ones, the warm ones lose heat and the cool ones gain it until they are all the same temperature.

Research on the cognitive and scientific basis

Research on student misconceptions

Strategies to check student understanding

Assessment activities

K-2

The sun warms the air, land and water.

Task-centered Design



- Lewis & Rieman, 1993
 - Involve users early and often
 - Focus on real needs and concrete tasks
 - Iterative design guided by frequent formative evaluation
- Analytic tools: inspections (cog WT, prog WT), ‘think-aloud’ verbal protocols, etc.
- Expanded view of interface and system

The Service in DLESE



DLESE Educational Resources For Educators News & Opportunities People & Groups For Developers

Browse Earth Concepts [Weather and Climate](#) > [Atmosphere](#)

[BACK](#)

To begin, pick a map from the selections below. Then, to see details, pick a strand and/or a grade range.

Pick a map

Pick a strand

Pick a grade range

9-12

- Life is adapted to conditions on the earth, including the force of gravity that enables the...
- The earth has a variety of climatic patterns, which consist of different...
- The cycle of water in the atmosphere plays an important role in...

6-8

- Climates have sometimes changed abruptly in the past as a result of changes in the...
- Human activities, such as reducing the amount of forest cover, increasing the...
- Gas and dust from large volcanoes can change the atmosphere...

3-5

- The earth is mostly rock. Three-fourths of its surface is covered by a relatively thin...
- When liquid water disappears, it turns into a gas (vapor) in the air and can...
- Air is a substance that surrounds us, takes up space, and whose movement we feel...

Benchmark

Climates have sometimes changed abruptly in the past as a result of changes in the earth's crust, such as volcanic eruptions or impacts of huge rocks from space. Even relatively small changes in atmospheric or ocean content can have widespread effects on climate if the change lasts long enough.

[Educational Resources](#)

[Student Conceptions](#)

[Related Ed. Standards](#)

[Related Benchmarks](#)

[Research on Benchmark](#)

Your search for

results 1 through 10 out of 294 ➔

"Climates have sometimes changed?"

had 294 matches.

Hurricane Backgrounder

<http://www.fema.gov/hazards/hurricanes/hurfacts.shtm>

This is the Hurricane site of the Federal Emergency Management Agency and one of its seventeen hazards pages. It contains the definition of a hurricane, its stages of development, and areas where they develop. Specific threats generated by hurricanes include hurricane force winds, rainfall and flooding, storm surge, and tornados generated by the hurricane. There is detailed information for each threat and a list of facts about tropical cyclone spawned tornados.

[Full description](#).

Natural Disasters: The Terror of Our Lives

<http://library.thinkquest.org/1003341/naturaldisaste/index.htm>

This website teaches students about natural disasters, including blizzards, earthquakes, hurricanes, tornadoes, volcanoes, fires, and avalanches. There are photographs of each disaster and safety tips as well as definitions of the disasters and information about where they are found. [Full description](#).

NSDL Strand Map Service



Service components

- Visualization interfaces →
- Web service protocol →
- AAAS information model →

User constituency

- K-12 teachers and students
- Library developers
- AAAS map makers and other staff

Visualization Interfaces Methodology



- Design, Develop and Evaluate a set of visual components which could be interconnected together usefully and usably
- Task-Centered Design
 - Requirements analysis - interview teachers
 - Design & Evaluation of Low-fidelity Mockups
 - Design & Evaluation of High-fidelity Interactive Prototypes
 - Integration Experiments
 - Demonstrator Interface for feedback at geoscience educator conference
 - Pilot study on how interfaces affect cognitive strategies
- Primary design outcome: set of components that protocol should support (expressiveness)

Prototype I



AAAS Standards - Index of Benchmarks

- **Nature of Science**
 - [Scientific Inquiry](#) (Evidence and Reasoning in Inquiry, Scientific Investigations, Scientific Theories, Avoiding Bias in Science)
- **Nature of Mathematics**
 - [Mathematical Inquiry](#) (Mathematical Processes, Mathematical Models)
- **Nature of Technology**
 - [Design and Systems](#) (Design Constraints, Design Systems)
 - [Issues in Technology](#) (Interaction of Technology and Society, Decisions about using Technology)
- **The Human Organism**
 - [Physical Health](#) (Disease, Maintaining Good Health)
 - [Mental Health](#) (Coping with Mental Distress, Diagnosis and Treatment of Mental Disorders)
- **Common Themes**
 - [Systems](#)
- **Habits of Mind**
- **The Physical Setting**
 - [The Universe](#) (Gravity, Solar System, Stars, Galaxies and the Universe)
 - [Processes That Shape The Earth](#) (Changes in the Earth's Surface, Plate Tectonics)
 - [Structure of Matter](#) (Atoms and Molecules, Conservation of Matter, States of Matter, Chemical Reactions)
 - [Motion](#) (Laws of Motion, Waves)
- **The Living Environment**
 - [Heredity](#) (DNA and Inherited Characteristics, Variation in Inherited Characteristics)
 - [Cells](#) (Cell Function, Cells and Organs)
 - [Flow of Matter and Energy](#) (Flow of Matter in Ecosystems, Flow of Energy in Ecosystems)
 - [Evolution of Life](#) (Biological Evolution, Natural Selection)
- **Historical Perspectives**
- **The Mathematical World**
 - [Mathematical Representation](#) (Graphic Representation, Symbolic Representation)
 - [Proportional Reasoning](#) (Ratios and Proportionality, Describing Change)
 - [Statistics](#) (Averages and Comparisons, Correlation, Statistical Reasoning)
- **Human Society**
 - [Behaviour](#) (Heredity and Experience Shape Behaviour, Culture Affects Behaviour)
 - [Social Change](#) (Influences on Social Change, Social Decisions)
- **The Designed World**
 - [Agricultural Technology](#)
 - [Communication and Technology](#) (Communication Technology, Computers)

Whole Space Navigator



Prototype I (contd.)



or its parts but appear because of the interaction of those parts.

Atoms and molecules are perpetually in motion, increased temperature means great average energy of motion, so most substances expand when heated.

Atoms may stick together in well-defined molecules or may be packed together in large arrays. Different arrangements of atoms into groups compose all substances.

Energy appears in different forms. Heat energy is in the disorderly motion of molecules.

In solids, the atoms or molecules are closely locked in position and can only vibrate. In liquids, they can slide past one another. Some molecules may get enough energy to escape into a gas.

explained by changes in the arrangement and motion of atoms and molecules.

Structure of Matter

	K-2	3-5	6-8	9-12
invisibly tiny pieces				
basic ingredients				
emergent properties				
heat energy				
changes of state				

↑
Cluster Navigator

Choose the grade level - topic combination of your interest, and then click on it's button in order to obtain the appropriate benchmarks

Heat Energy :
Grades 9-12
 The arrows indicate learning dependencies. Click on individual benchmarks for more information and associated resources. which will appear in the box below.

Sub Strand Viewer

Benchmark Information Viewer

Resources :

Periodic Table of the Elements

An interactive version of the Periodic Table of the Elements. Each element is linked to a wealth of information concerning basic chemical properties, as well as short descriptions of its history, sources, compounds, uses, and isotopes. . .

Grade Level: Graduate or professional, High school, Intermediate elementary, Middle school, Undergraduate lower division, Undergraduate upper division

Resource Type: Reference

Done
My Computer

Prototype II



Map Tree Navigator

- StrandMaps
 - The Nature of Mathematics
 - The Nature of Technology
 - The Physical Setting
 - Motion
 - Structure of Matter
 - Atoms and Molecules
 - States of Matter
 - Emergent Properties
 - Grades K-2
 - Grades 3-5
 - Grades 6-8
 - Grades 9-12
 - Heat Energy
 - Changes of State
 - The Universe
 - The Human Organism
 - Mental Health
 - Physical Health
 - The Designed World
 - The Mathematical World

Sub Strand Viewer

Emergent Properties: Grades 3-5
The arrows indicate learning dependencies. Click on individual benchmarks for more information and associated resources.

All matter is made up of atoms, which are far too small to see directly through a microscope.

Air is the substance that surrounds us and takes up space.

Collections of pieces (powders, marbles etc) may have properties that the individual pieces may not.

Benchmark Information Viewer

Details about this set of benchmarks:
The study of materials should continue and become more systematic and quantitative. Students should design and build objects that require different properties of materials. They should write clear descriptions of their designs and experiments, present their findings whenever possible in tables and graphs (designed by the students, not the teacher), and enter their data and results in a computer database.

Objects and materials can be described by more sophisticated properties—conduction of heat and electricity, buoyancy, response to magnets, solubility, and transparency. Students should measure, estimate, and calculate sizes, capacities, and weights. If young children can't feel the weight of

Done My Computer

Integration Experiment: DLESE



DLESE

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Register with DLESE

Digital Library for Earth System Education

Funded by the National Science Foundation

What's new at DLESE

- DLESE 2004 Annual Meeting - watch for registration information in April 2004
- DLESE Diversity portal
- New resources & reviews
- Resources about Mars: DLESE/MarsQuest Online
- Welcome to Version 2 of DLESE!
 - Search by National Science and Geography Standards
 - Search multiple collections of resources: Review DLESE resources. Please give us feedback.

Res

Strand Maps

- Processes That Change The Earth
 - Changes in the Earth's Surface
 - Earthquakes and Volcanoes
 - Rates of Change
 - Weathering and Erosion
 - Rocks and Sediments
 - Plate Tectonics

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 [weathering and erosion](#) |
 [rocks a](#)

9-12

Scientific evidence implies that some rock near the earth's surface is several billion years old.

[View Related Resources](#)

The formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change.

[View Related Resources](#)

earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands. [View Related Resources](#)

6-8

The interior of the earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins. [View Related Resources.](#)

The earth's surface is shaped in part by the motion of water (including ice) and wind over very long times, which act to level mountain ranges. Rivers and glacial ice carry off soil and break down rock, eventually depositing the material in sediments and carrying it in solution to the sea. [View Related Resources](#)

3-5

Waves, wind, water and ice shape and reshape the earth's land surface by eroding rock and soil in some areas and depositing them in other areas, sometimes in seasonal layers. [View Related Resources](#)

Thousands confirm the surface of the earth forms in successive layers that are not always folding, but... [View Related Resources](#)

There are a lot of rivers, mountains, and... [View Related Resources](#)

Things on or near the earth are pulled toward it by earth's gravity. [View Related Resources](#)

The earth first formed in a molten state and then the surface cooled into solid rock. [View Related Resources](#)

Vibrations in materials set up wave-like disturbances that spread away from the source. Sound and earthquake waves are examples. [View Related Resources.](#)

Some changes in the earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains). [View Related Resources](#)

Sedimentary rock buried deep may be reformed by pressure and heat, perhaps melting and recrystallizing into different kinds of rock. These reformed rock-layers may be forced up again to become land surface and even mountains. Subsequently this rock too will erode. Rock bears evidence of the minerals, temperatures and forces that created it. [View Related Resources](#)

DLESE introduces a new way of finding teaching materials and resources in the library, using conceptual Strand Maps. These maps are visual representations of how K-12 learning goals for a particular topic relate to each other and progress from one grade level to the next. Each map is cross-referenced horizontally by grade levels (K-2, 3-5, 6-8 and 9-12), and vertically by "strands" of specific topics.

Arrows between individual boxes on the maps indicate learning dependencies. You can click on the individual boxes, in order to access teaching materials and activities aligned with concepts in each box.

CSIP Web Service Protocol



Balance expressiveness with facility

- expressiveness -> visual components
- facility -> programming walkthrough

- Representational State Transfer (REST)
- Protocol consists of three services
 - Service Description
 - Submit Resource
 - Query

```
<Query DetailLevel="Detailed" Format="SVG" Scope="MAP">
```

```
<Content-Query>
```

```
<Name MatchType="Equal">Weather and Climate</Name>
```

```
</Content-Query>
```

```
</Query>
```


Programming Walkthrough Analysis Guidelines



- How long is the process?
- Are there opportunities to eliminate steps by changing the design?
- Are there steps for which it was not possible to describe knowledge that would guide their selection? (these steps will require extensive problem solving by programmers)
- Conflicts among points of guiding knowledge?
- Conflict between guiding knowledge and the knowledge user brings with him?
- Unclear correctness of steps
- Are there steps that require knowledge that programmers are unlikely to have?

Programming WT Process



- Two rounds, with changes after each
- Round 1: Two walkthroughs (3 and 2)
 - Each group asked to perform 5 tasks
 - About 2 - 2.5 hours to complete
- Round 2: Two walkthroughs (2 and 1)
 - same tasks

CSIP Evaluation Results



- No major expressiveness issue found
- Facility
 - × Documentation issues
 - × Terminology issues
 - ✓ Adequate design guidance
 - ✓ Standardized query construction approach
 - ✓ No major design issues revealed

AAAS Information Model



- Methodology
 - Iterative model
 - Participatory design - map maker part of team which also included metadata experts, developers
 - Analysis tool: Concept Space characterization matrix
 - Rubric Evaluations
- Outcome: Concept Space Metadata Framework v1.0, preliminary best practices, and confidence that the AAAS map makers could catalog to this

CSMF Evaluation Rubric Questions



- Set of relationships. Do we have expressive enough relationships to capture all aspects of concept maps and AAAS project 2061 domain?
- How to express relationships that will maintain the concept map structure and require minimal effort in cataloging
- Test external standard relationship field and check for its adequacy
- Test external resource relationship field and check for its adequacy
- Try out narrative (Student | Examples | Assessment | Instructional | Clarification) ideas and define their usability and exact semantics and best practices
- Check the appropriateness and completeness of data that form basis of Strand Map Service
- Check completeness of admin fields
- Check for redundancy and anomalies in fields
- Identify cataloging sequence (top-bottom, bottom-top, parallel etc)
- Make sure when a complete range of objects are cataloged they make a coherent navigable, discoverable and logical path

CSMF Evaluation Results



- No major design alteration
- Minor issues revealed
 - Communication
 - Best practices
 - Benchmark to Strand relationship

Conclusion



- Pilot research study results on cognitive strategies are encouraging
- We have a growing list of partners for the Service
 - Deployment cases are next step - TCD process continues but in more operational contexts
 - Major research projects
- Generalizability to other concept spaces
- Impact on the mindset and practices of our partners