3-D EDUCATION: TEACHING K-12 FOR HIGHER-ORDER THINKING

(Science)

By: Patrick J. Leighton, Ed.D.

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TEACHING K-12 FOR
HIGHER-ORDER THINKING

Introduction:

This document is intended for an audience of teachers of the academic subjects, with the majority in science. Although many of the examples and exercises are related to science, the body of the content is generic to all of the academic subjects. At this time The Curriculum Library only includes science materials, but the intention is to quickly expand to math, English & Literature, and History & Social Studies.

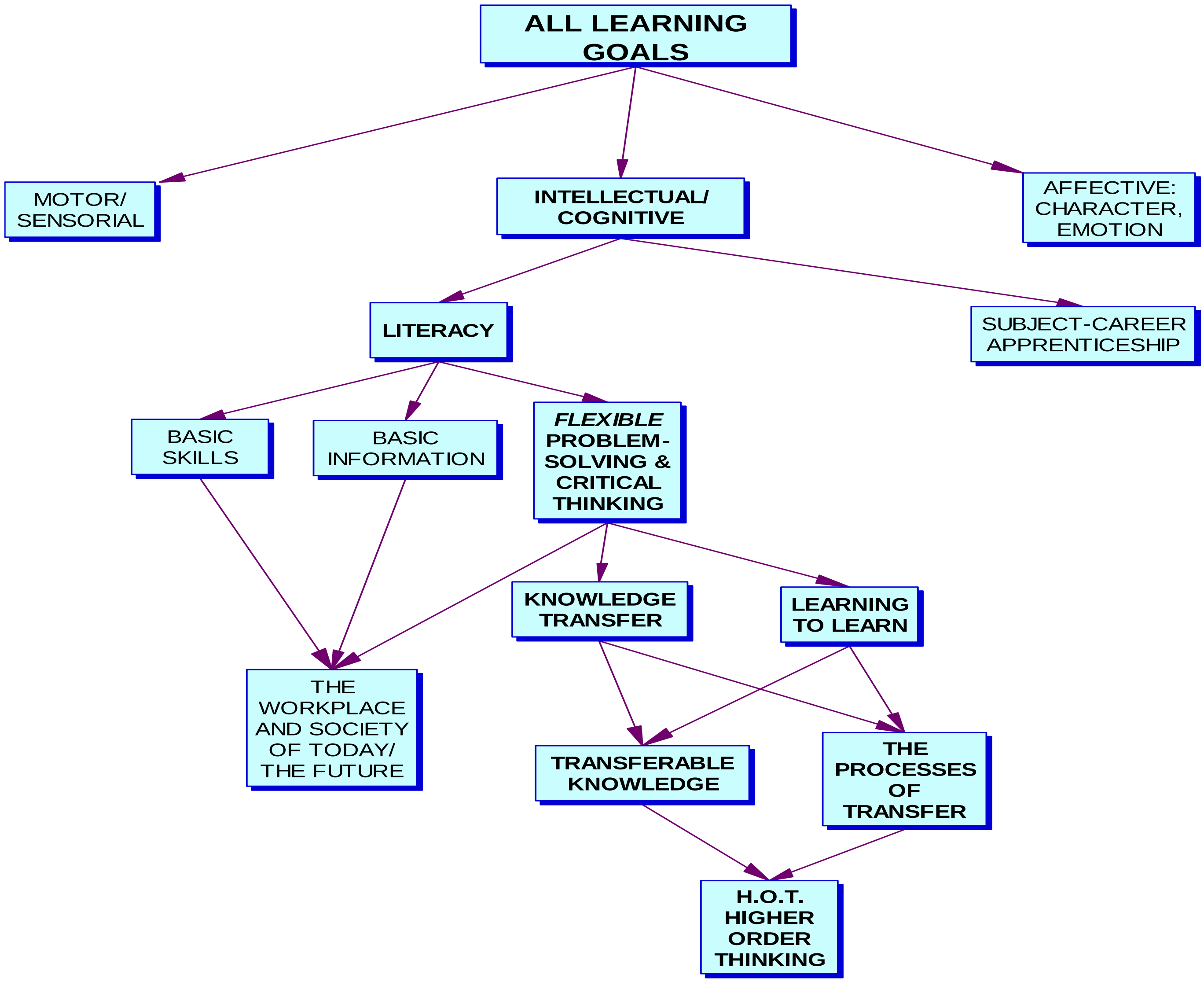
This document is a flip book of frames developed for a three day professional development program. Exercises and questions are interspersed throughout. Flipping through the frames should give you a quick first impression, particularly if you are familiar with the vocabulary of classroom practice. Working from frame to frame and carrying out most of the tasks should provide an in-depth understanding of how to use 3-D Education in your (science) classroom so students learn higher order thinking.

This professional development program is intended to provide you with a solid educational foundation in HOW you would use The Curriculum Library to your students' maximum advantage. The Library, in the end, is a tool for teachers. Any possible lesson can be cataloged and accessed, so a teacher could use the Library to choose any possible sequence of lessons. This professional development program is intended to show you how you would make choices using the flexibility of the Library's cataloging to keep teaching and learning focused on higher-order thinking.

CHAPTER I

- **THE GOALS FOR STUDENT LEARNING**
- **INTRODUCTION TO 3-D CURRICULUM**

CATEGORIES OF LEARNING OUTCOMES



LITERACY: The command of information, skills, concepts and thinking processes required for personal decision-making, economic productivity, and effective participation in civic and cultural affairs in rapidly changing workplaces and societies. Assessment of such literacy would provide students with the opportunity to demonstrate their knowledge of basic information and skills and, more importantly, to apply their understanding of the essential, transferable concepts characteristic of the major domains of knowledge to new, unpredictable phenomena, contexts, issues, and questions.

OUR LEARNING GOAL FOR ALL STUDENTS:

SCIENTIFIC LITERACY

Scientific literacy means that students will:

- **know the important information and skills, and**
- **understand the basic concepts**

as evidenced by ...

- **Problem solving and critical thinking that is flexible and inquiry based,**

And in which they

Direct their own choices and uses of information, skills, and concepts when addressing a question.

THE ULTIMATE GOAL OF LITERACY:

PROBLEM SOLVING, CRITICAL THINKING, REASONED DECISIONS

Students can transfer previously learned knowledge to new questions. They can answer, address, or investigate questions in a creative, insightful, fruitful, and/or enjoyable way, and they can effectively communicate this process to others.

Students can address a wide variety of questions, including questions that they have not previously considered or questions in unfamiliar contexts.

that are

FLEXIBLE

and

INQUIRY-BASED

Students motivate and orchestrate their own problem solving and critical thinking. They develop their own questions, design and carry out procedures appropriate for the question, modify the question and procedure as they progress, and use newly acquired knowledge as a basis for further inquiry.

which Bloom (1956) defined as the ability to orchestrate six cognitive processes:

INFORMATION

COMPREHENSION

These involve learning ***the essential facts and skills.*** *Facts and information are specific to a particular topic, situation, context, or phenomenon.*

basic thinking skills

---

higher-order thinking processes

APPLICATION

ANALYSIS

SYNTHESIS

EVALUATION

These involve

KNOWLEDGE TRANSFER

Introduction to 3-D EDUCATION

Fred Newman et al:

INSTRUCTIONAL PROGRAM COHERENCE

•A set of inter-related programs guided by a common framework for curriculum, instruction, assessment and learning climate that are pursued over a sustained period.

•Leads to improved student achievement vs. uncoordinated efforts limited in scope and duration

Newman, F.M., Smith, B., Allensworth, E. Bryk, A.S. (2001) Instructional Program Coherence: What it is and why it should guide school improvement policy. Educational Evaluation and Policy Analysis, 23(4), 297-321.

3-D

CONCEPT - BASED EDUCATION

Connecting Standards Alignment and Curriculum Coordination with High Student Achievement Through Cognitive Science

SOCIETY NOW DEMANDS:

HIGH ACHIEVEMENT

SCIENTIFIC LITERACY FOR ALL STUDENTS

No longer:

- **Narrow career or vocational preparation**
- **Weeding out students and focus on elite**

SCIENTIFIC LITERACY FOR THE 21ST CENTURY:

All students will:

1. a. Know the important information and skills

b. Readily access and comprehend new information and skills

Introduction to 3-D EDUCATION

SCIENTIFIC LITERACY FOR THE 21ST CENTURY:

All students will:

2. a. Understand the basic concepts of science

As evidenced by …

b. Problem solving, critical thinking, & considered decision making that is flexible and transferable

SCIENTIFIC LITERACY FOR THE 21ST CENTURY:

All students will:

3. Direct their own choices and uses of information, skills, and concepts when addressing a question

To design a model for teaching and learning higher-order thinking,

use what

Cognitive Science

has learned over the past

15+ years about

the intellect and academic thinking

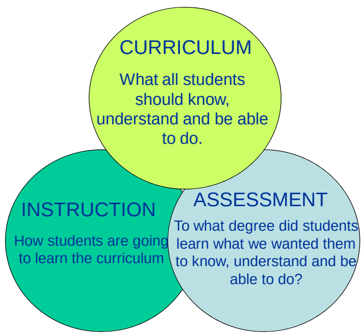
Concept-Based Education:

Focused on Higher-Order Thinking (H.O.T.)

-

Focused on Classroom Practice

Introduction to 3-D EDUCATION



THE THREE PARTS OF CLASSROOM PRACTICE

THE ESSENTIAL QUESTION BEING ASKED OF EDUCATORS:

" Why are our kids not learning at the rate that they should be despite decades of reforms and budget increases? "

TIME magazine, April 19, 2010 p. 42, "Is Cash the Answer?"

50+ YEARS OF DEVELOPMENT AND INNOVATION IN EDUCATION

- Cooperative learning
- Open-ended assessment
- Project-based learning
- Computer-aided instruction
- Authentic assessment
- State curriculum standards
- Learning objectives
- Inquiry-based learning
- Peer assessment
- Rubric design
- Problem-based learning
- … etc., etc., etc., etc., etc.,

So where are the effects on student learning ???

A PATTERN:

Cooperative learning
Project-based learning
Computer-aided instruction
Inquiry-based learning
Hands-On experimentation
Differentiated Instruction
Problem-based learning
… etc., etc., etc.,

Instruction: LOTS !

Authentic assessment
Open-ended assessment
Peer assessment
Rubric design
Formative assessment
Summative assessment
… etc., etc., etc

Assessment: LOTS !

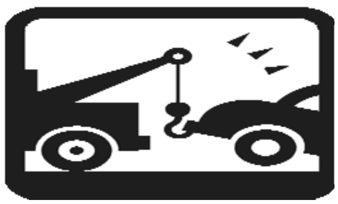
Learning objectives
State curriculum standards

Curriculum ??

Little but behaviorism for 100 years

THESIS

THE IMPROVEMENTS IN ASSESSMENT AND INSTRUCTION ARE BEING STYMIED BY A LACK OF PROGRESS ON CURRICULUM



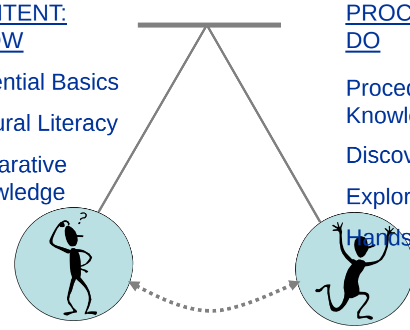
THE ZERO-SUM PENDULUM SWING IN CURRICULUM

CONTENT: KNOW

- Essential Basics
- Cultural Literacy
- Declarative Knowledge
- Text

PROCESS: DO

- Procedural Knowledge
- Discovery
- Exploration
- Hands-On



HIGH ACADEMIC ACHIEVEMENT

means students…

✓KNOW the essential information

✓UNDERSTAND the basic concepts

✓CAN DO the essential skills

Ultimately demonstrated by

✓PROBLEM SOLVING AND CRITICAL THINKING

The Holy Grail of High Student Achievement:

PROBLEM SOLVING AND CRITICAL THINKING

The Higher Thinking Processes: Application, analysis, synthesis, judgment

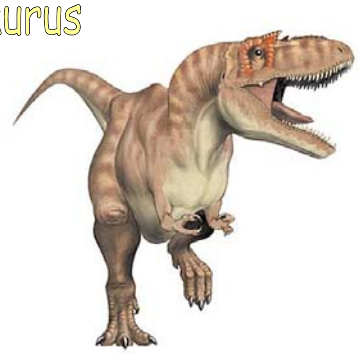
=

KNOWLEDGE TRANSFER

An operational definition

Introduction to 3-D EDUCATION

Gorgosaurus



What do students learn when they study dinosaurs?

IDEA ADDED 1-28-09

- COULD ALSO USE “ANCIENT EGYPT” HERE. At K-12 Coventry workshop (200 teachers) many teachers responded with having had taught such a unit at some time in their career

WHAT STAYS BEHIND ?

Gorgosaurus

Ferns and swamps

Big, bad, ugly, extinct

- **specific contexts, exemplars, information**

= topic

WHAT MOVES ?

Form-and-function

- Transferable concepts

definable (generalizations, maps, text)
universal, timeless

Introduction to 3-D EDUCATION

HOW DOES IT TRAVEL?

HIGHER ORDER PROCESSES

- Application
- Analysis
- Synthesis
- Evaluation

Can you create an insightful question relating the following topics to each concept?

Concept	**Topic**
❖Energy Transformation	❖ Light bulb
❖Interdependence	❖ Tree
❖Motion and Forces	❖ Aspirin
❖Form and Function	❖ Skateboard

On a scale of 1-5 how insightful would your questions be for each concept?

KNOWLEDGE TRANSFER

When confronted with a novel problem or question:

What transfers from prior knowledge? → TRANSFERABLE CONCEPTS **(“understand”)**

What is the new context? What “stays behind” ? → **TOPIC/CONTEXT** INFORMATION **(“know”)**

How does it move? → SKILLS AND PROCESSES (“do”)

THE CONCEPT-BASED PARADIGM OF CURRICULUM

CONCEPT — **TOPIC INFORMATION**

PROCESSES AND SKILLS

- ✓**INCLUSIVE OF CONVENTIONAL PARADIGM**
- ✓**SPECIFICALLY DESIGNED TO GENERATE KNOWLEDGE TRANSFER**
- ✓**THE PATTERN OF LIFE-LONG LEARNING AND FLEXIBILITY**

Introduction to 3-D EDUCATION

THE CONVENTIONAL PARADIGM OF CURRICULUM

CONTENT PROCESS

✓CANNOT GENERATE KNOWLEDGE TRANSFER

✓COMPREHENSION IS THE MAXIMUM LEVEL

CONCEPT BASED EDUCATION =

TWO MAJOR SHIFTS IN THINKING ABOUT CURRICULUM

I.

THERE ARE *THREE* TYPES OF LEARNING OUTCOMES:

a) topic/context information "KNOW"
b) transferable concepts "UNDERSTAND"
c) skills and processes "DO"

II.

THE HIGHER THINKING PROCESSES CAN ALL BE OBJECTIVELY DEFINED (AND THEREFORE ASSESSED) AS DIFFERENT METHODS OF COMBINING TRANSFERABLE CONCEPTS WITH SPECIFIC TOPIC AND CONTEXTUAL INFORMATION.

THESIS RESOULTION:

BREAKING THE LOG-JAM

The improvements in student learning generated by a concept-based model of curriculum will be compounded by the anticipated improvements in learning flowing from the innovations in assessment and instruction that were previously stymied.

Educational concern: ACCOUNTABILITY FOR STANDARDS

Any and all curriculum standards can be analyzed and then categorized for their focus on concept, information, or process/skill.

Curriculum is aligned with mandated standards as well as with cognitive science and learning theory.

Assessment of students' concept transfer, information command, and skill/process abilities is objective.

II

- **THE THREE DIMENSIONS OF CURRICULUM: CONCEPT, TOPIC, SKILL**

- **DEFINING TRANSFERABLE CONCEPTS**

THE THREE DIMENSIONS OF CURRICULUM

- **TRANSFERABLE CONCEPTS** — *(i.e. general principles, basic understandings, laws, big ideas). The essential characteristic of concepts is that they are applicable to a wide variety of topics: they are transferable. (E.g. evolution, eulogy, average)*

- **TOPICS** — *(i.e. specific facts, contexts, phenomena, situations). Topics are characterized by information that describes observations and concrete experiences. They are grounded in perceived reality. Topics can be very important, yet not be concepts (e.g. plate tectonics, the bible, the Renaissance).*

- **SKILLS/ PROCESSES** — *(i.e. doing, communicating) Skills usually involve some form of physical action (measuring, writing, mapping) and/or can be performed as a scripted procedure. Higher-order thinking processes usually involve some form of mental action (comparing, analyzing, inferring) that must be orchestrated by the learner and manipulate the characteristics of the question or problem context.*

AS COMPARED TO

- **CONTENT** — *A mixture of all manner of concepts and topics, with little distinction made among them. Content is sometimes referred to as declarative knowledge.*

- **SKILLS/ PROCESSES** — *Same as in the three dimensional model. Skills and processes are often referred to as procedural knowledge.*

THE DISTINCTION OF CURRICULUM INTO THREE DIMENSIONS IS THE FIRST OF TWO MAJOR SHIFTS IN THINKING ABOUT CURRICULUM DESIGN AND PLANNING

CONCEPT-BASED PRACTICE IN A NUTSHELL

All concept-based models of classroom practice see learning and teaching as having three dimensions:

CONCEPT	TOPIC	SKILL, PROCESS
aka: Transferable concept Principle Generalization Enduring understanding	aka: Context Literary Genre, Title	aka: Performance Kinesthetic Cognitive

The various combinations of the 3 dimensions create different depths of learning. Most usefully:

CONCEPT + SKILL / PROCESS + TOPIC = Higher Order Thinking

aka:
- flexible, inquiry-based, problem solving
- critical thinking
- reasoned decision making
- Application, analysis, synthesis, evaluation, creativity

Conceptual framework provides:

- Connections among learned topics and other concepts
- Long-term memory and rapid recall
- Timeless and universal application
- Focus and precision of learning, instruction & assessment directed at H.O.T.

THE QUICK DIFFERENCE IN THE MIND'S EYE:

TRANSFERABLE CONCEPT	**WHITE** **(no image – all colors blend to no color)** **-** **LINK TO QUESTIONS &** **H**igher **O**rder **T**hinking
TOPIC CONTEXT TITLE	**PICTURE** **-** **LINK TO FACTS & INFORMATION**
SKILL PROCESS	**ACTION** **-** **LINK TO PERFORMANCE**

EXAMPLE CONCEPTS, TOPICS, AND SKILLS

	CONCEPTS	TOPICS	SKILLS
SCIENCE	mass energy interdependence form-follows-function	insects weather rain forest fossil fuels mitosis	experimenting: using instruments recording data plotting graphs web browsing
MATH	property/variable pattern ratio slope	pizza consumerism science topics demographics	reading decimals multiplication facts order of operations drawing circles
LITERATURE	metaphor symbolism diction antagonist	Phantom Tollbooth Romeo and Juliet Greek mythology poetry	spelling punctuation capitalization grammar
SOCIAL STUDIES	conflict interdependence trade belief	Native Americans southeast Asia Industrial Revolution the Civil War	reading maps constructing charts library research group discussion

SCIENCE TOPIC CHOICES

PHYSICAL SCIENCE and TECHNOLOGY	EARTH SCIENCE	CHEMISTRY	LIFE SCIENCE	HUMANITIES	VOCATIONAL, CAREER
EVERYDAY EVENTS AND ENVIRONMENTS Misc	**GEOLOGY** Plate Tectonics Volcanoes, Earthquakes Land Forms Erosion, Deposition Misc.	**CHEMISTRY** Organic Chemistry Biochemistry Misc	**ANIMALS** Pets Wildlife Animal husbandry Misc.	**SOCIOLOGY** History, Government Biography Misc	**BUSINESS** Economics Finance Misc
ENGINEERING, GENERAL Mechanical, Industrial, Manufacturing Engineering Misc	**SOIL SCIENCES, CIVIL ENGR.** Landscaping Mineralogy Misc.	**CHEMICAL ENGINEERING** Synthetics Misc	**PLANTS** Misc.	**LAW / ETHICS** Ethics, Values Morals, Religion Misc	**CONSUMERISM** Misc
ENERGY TECHNOLOGY Misc	**METEOROLOGY** Atmospheric Sciences Misc	**ENVIRONMENTAL CHEMISTRY** Waste Disposal Recycling Misc	**BIOLOGY** The Cell Botany Zoology Misc	**PSYCHOLOGY** Education Children Misc	**SERVICE TRADES** Home / Building Maintenance Beauty / Grooming Culinary Arts Misc
ELECTRONICS and MEASUREMENT INSTRUMENTS Measurement instruments Misc	**NATURAL RESOURCES** Misc		**HEALTH, MEDICINE, HUMAN BODY** Physiology, Organ Systems The Senses Misc	**MATHEMATICS** Misc	**BUILDING TRADES** Excavation, Landscaping Misc
INFORMATION, COMMUNICATION, MEDIA Computers Misc	**ASTRONOMY** Solar System Cosmology Misc		**FOOD** Agriculture Agronomy Misc	**ANTHROPOLOGY, ARCHEOLOGY** Misc	**MANUFACTURING TRADES** Misc
SPORT, PHYSICAL EDUCATION, RECREATION Dance Self-defense Misc	**OCEANOGRAPHY** Misc		**ECOLOGY** Environmental Zoology & Botany Forestry Misc	**ART, CRAFT** Music Dance Misc	**FARMING** Misc
TRANSPORT Land Transport Water Transport Air Transport Space transport Misc			**PALEONTOLOGY** Misc	**LANGUAGE** Literature Literal Interpretation Figurative Devices Misc	
MILITARY Misc					
SPACE TECHNOLOGY Misc					

SKILL HIERARCHIES FOR SCIENCE, TECHNOLOGY, ENGINEERING, AND DESIGN.

MAJOR CATEGORY	SUB-CATEGORY	SUB-SUB-CATEGORY
EXPERIMENTAL METHOD	QUESTION, HYPOTHESIS, PURPOSE	
	PROCEDURE, METHOD	OBSERVATION • Qualitative (non-numerical) • Quantitative (numerical)
		CONTROLLED EXPERIMENT • (in)dependant variables • controlled variables • control
		TRIAL AND ERROR
		CONTROLLED EXPERIMENT
		SURVEY
		INTERVIEW
		SECONDARY SOURCE
	RESULTS, DATA, OBSERVATIONS	
	CONCLUSION, ANALYSIS	
PROCEDURAL PROBLEM SOLVING • algorithm	SEQUENCE, COORDINATION	
	AND, OR	
	IF…THEN	
DESIGN PROCESS	IDENTIFY PROBLEM	CRITERIA, CONSTRAINTS
		RESOURCES
	GATHER INFORMATION • evidence	
	DEVELOP MULTIPLE OPTIONS	
	SELECT, REFINE, DESIGN SOLUTION	
	CONSTRUCT SOLUTION/PROTOTYPE • pilot, field test	
	EVALUATE SOLUTION	COSTS, BENEFITS, TRADE-OFFS
		EFFICIENCY, EFFECTIVENESS
	COMMUNICATE SOLUTION	
	RE-DESIGN SOLUTION	

THE FOUR STAGES OF SCIENTIFIC INQUIRY

- **Every lab report must include at least one section from each stage.**
- **Your report must follow the 4-stage sequence. The order of the sections can change.**
- **The bold and underlined sections indicate those most commonly used.**

Think of the four stages as the steps you would follow to plan and then go on a vacation trip:

"Where/Why do you want to go?"

STAGE ONE:

Title: Always included
Possible other sections:
Introduction
Background
Concept
Question
Problem

Purpose

Hypothesis

"How are you going to get there?"

STAGE TWO:

Possible sections:
Procedure
Method
Instructions
Materials List
(Equipment) Diagram
Safety

"Do it! Go!"

STAGE THREE:

Possible sections:
Observations (non-numerical)
Data (numerical)
Readings

NOTE:
This stage describes
- The things or substances being described
- The properties being used for description
- The values and units of measurements for the properties

"Is this where you expected to be?"

STAGE FOUR:

Possible sections:
Interpretation (usually addresses observations)
Analysis (Usually addresses data. Includes calculations, graphs)
Error Analysis
Conclusion
Recommendations
Results

Stage 4 respond

TASK: FOR EACH OF THE ITEMS LISTED IN COLUMN ONE, IDENTIFY IT AS A CONCEPT, TOPIC, OR PROCESS/SKILL

(Place a check mark in the appropriate box to make your choice)

	CONCEPT	TOPIC	SKILL/PROCESS
1. Evolution			
2. Water			
3. Graphing			
4. Force			
5. Pollution			
6. Microscope use			
7. Change			
8. Weighing			
9. Plate tectonics			
10. Interdependence			
11. Nomenclature			
12. Configuration			
13. Electron Configuration			
14. Graph			

DEFINING A CONCEPT IS THE BASIS FOR ASSESSING IT

A group of fifth grade teachers decided to use the theme of CHANGE to focus the year's science program. They assembled the following collection of topics as representative of what change meant. The topics were to be covered during the year by all teachers. As a final assessment at the end of the year, students were to choose their own topic that illustrated CHANGE and prepare a class presentation.

CHANGE:

Seasons	Volcanoes	Environment
Light and shadow	Matter	Nature
Metamorphosis	Farms	Growth
Earth	Weights/measures	Weather
Snow, ice, water	Cooking	Plants
Eggs	Birds	Transport

Taken from ASCD Manual 1996, Folder 3, Activity 3

1) If you had interviewed students during their final presentations, what understandings of the concept of CHANGE would you expect them to have formed over the course of the year?

2) How could the concept of CHANGE be defined in order to give a common approach to comparing and analyzing each of these? What do each of the listed topics have in common that could be identified as the concept of CHANGE?

3) Given this definition or common set of attributes, create an example of an assessment task that would measure a student's degree of understanding of CHANGE.

A CONCEPT DEFINITION IS…

A. The key to teaching transferable understanding rather than terminology.

B. A way to distinguish between themes or topics and bona fide transferable concepts.

C. A way to remove subjectivity, personal opinion and preference from the process of identifying transferable concepts and designing curriculum.

D. A way to arrive at an objective, professional consensus on the specifics of what students are to learn.

E. THE LINK BETWEEN CURRICULUM AND ASSESSMENT.

F. The dimensions and parameters for measuring conceptual understanding and transfer-ability.

G. The basis for constructing the rubric for assessing student understanding and transfer-ability.

THREE FORMATS FOR DEFINING A CONCEPT

These three formats are largely interchangeable, even though each has its own advantages. Different people will prefer one or another depending upon their own preferences and learning styles.

1. TEXT EXPLANATION

- *Familiar*
- *Evocative examples and illustrations*
- *Focus on types of questions for which the concept is useful*
- *Include analogies*

2. ESSENTIAL GENERALIZATIONS

- *Distillation of essential component understandings*
- *Direct connection to assessment*

3. CONCEPT MAPS

- *Graphic display*
- *Emphasis on connections among component concepts*
- *Valuable instructional strategy*

Two important points:

Such definitions of concepts attempt to identify the MINIMUM ESSENTIAL parts of the concept that create a recognizable, coherent, discrete whole. Each person's actual understanding of a concept is generally far more elaborate as learning and life experiences add details and connections with other concepts. Since every person's learning and experiences are unique, his/her ultimate understanding of a concept is also unique. The definitions of concepts used for curriculum planning and design are "starter packages" that are at least capable of being transferred among a variety of questions and topics. Later learning of other concepts and topic applications will "back-load" a deeper and more robust understanding.

Concepts by their very nature are connected to other concepts. On the other hand, topical information differentiates a particular context or phenomenon from another, and is therefore isolated or segregated from other topics. Concepts exist within a structure of connections to all other concepts, and these connections largely define a concept.

DEFINING THE CONCEPT OF CHANGE/PROCESS

SYNONYMS: change, process, event, happening, occurrence, phenomenon.

TEXT DEFINITION:

The world that surrounds us is made up of objects and materials. We walk over rocks, breath air, and swim in water. The moon hangs overhead while bacteria populate our skin. Yet every possum knows a secret: do nothing and nobody will notice you. Change is what catches the eye. The ocean is more interesting than a quiet lake because it changes. Waves, surf, tides, and currents create a show worth watching. The events that happen around us are what fascinate us.

Yet without the things and stuff of existence there would be no change. Every process must involve objects or substances, just as every schoolyard game must involve players. A sunset cannot happen without the sun and an atmosphere. Disease and sickness often involve microscopic players called bacteria as well as our organs. Our oceans rise and fall twice a day because of an unlikely player, the moon.

During any process or event, the involved things and substances change, but what does this mean? The moon is still the moon this month and last, even though it has caused many tides in between. A student kicks a ball into the goal, yet the student and ball are still there, ready to do it all over again. During any process, the properties of the things and substances change. The ball changes speed and location when the student kicks it. The moon actually slows down slightly with every tide.

Change means that the values of properties change, and there is a simple pattern to all such changes. They always take time. The tides take about 12 hours to rise and fall, and the sun takes several minutes to drop below the horizon. Although it might seem to our human senses that a glass breaks instantaneously when it hits the floor, it actually takes a small amount of time to go from one whole to many shattered pieces.

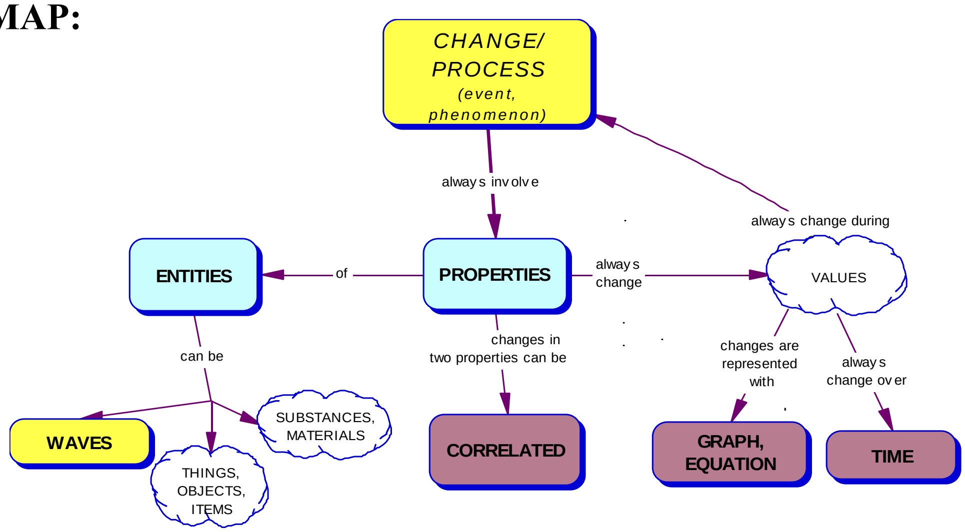
GENERALIZATIONS:

1. All changes, processes and events involve things, substances or waves.

2. During any change, properties of the involved things/substances/waves change values.

3. The changes in property values that occur during any process always take time.

CONCEPT MAP:



PROCESSES: WHAT'S CHANGING, AND HOW IS IT CHANGING?

Describe each of the following processes by:

A) State the name of the process
B) Identify an important thing or substance whose properties change during the process,
C) Identify a property that is changing values during the process,
D) i.) What is a possible value of this property at the beginning of the process
ii.) At the end of the process

There are several ways to describe many of the listed processes, so don't worry about right and wrong answers. If you want, you may describe a more specific thing or substance than the one listed. For example, instead of FLOWER, you could say ROSE.

EXAMPLE:
A) PROCESS: Stapling paper together
B) THING/SUBSTANCE: Staple
C) PROPERTY: Shape.
D) BEGINNING VALUE: Open-box shape, with the ends bent to make the corners.
E) ENDING VALUE: Squashed-box shape, with the ends bent up against the back staple.
F) TIME: About half a second, maybe less.

PROCESSES: (Use the format given in the example above)

1) Trees changing color during New England fall.
2) A picture fading in the sun.
3) A flower blooming.
4) A child growing up.
5) A banana rotting.
6) The sun setting over the ocean.
7) A mountain climber climbing a mountain.
8) Chewing food.
9) A bathtub being filled.

For each of the following processes, you **must** choose a numerical property.

10) A sunbathing person.
11) A motorcycle with its engine idling.
12) A wink.
13) Snow falling on a forest of pine trees.
14) A gravestone slowly being eaten by acid rain.
15) A dirt bike jumping through the air.
16) Someone smiling
17) A pond evaporating in the sun.
18) Sharpening a pencil.
19) A person shoveling snow.
20) A basketball being dribbled.

III.

WHAT ARE THE RELATIONSHIPS:

- **Among Concepts, Topics, and Skills/Processes**

- **Between Teaching Content and Teaching for Transfer**

- **Among Different Concepts**

THE ESSENCE OF … HIGHER THINKING:

problem solving
critical thinking
reasoned decision making
application
analysis, synthesis
judgment
intellectual creativity

= KNOWLEDGE TRANSFER

TRANSFERABLE CONCEPT	+	TOPIC AND CONTEXT	=	HIGHER THINKING PROCESSES
Carefully identified and clearly defined		Interests accommodated and variety explored		Students initiate questions and orchestrate thinking processes and investigations in different contexts and situations

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The insight that all of the higher thinking processes are fundamentally different ways of combining generic, transferable concepts with specific topics and contexts is the

SECOND OF THE TWO MAJOR SHIFTS IN THINKING

about curriculum design and planning contained within the model of concept-based education.

The Holy Grail:	• HIGH END OF BLOOM'S TAXONOMY • PROBLEM SOLVING • CRITICAL THINKING • FLEXIBLE, ADAPTABLE APPLICATION • SELF-DIRECTED, LIFE-LONG LEARNING
Operational Definition:	**KNOWLEDGE TRANSFER** **All higher order thinking involves transferring knowledge from a familiar context to one that is novel in order to address a question.**
What Transfers?	**TRANSFERABLE CONCEPTS**
What Stays Behind?	**TOPIC/CONTEXT INFORMATION**
How Does It Move?	**HIGHER-ORDER THINKING PROCESSES = HIGH END OF BLOOM'S TAXONOMY**

CONCEPTS AND SKILLS

both TRANSFER,

but *DIFFERENTLY*

CONCEPT		SKILL
TRANSFER…	TOPIC	TRANSFER…
… • Ignores surface similarities of topics • Focuses on deep differences in knowledge structure • Activated by questions that are to be addressed		… • Focuses on surface similarities of topics • Ignores deep differences in knowledge structure • Activated by facts and information that are to be manipulated
= Higher-order thinking		= Skill fluency and comprehension

BLOOM'S TAXONOMY
OF THINKING PROCESSES:

BASIC THINKING SKILLS:

1) KNOWLEDGE (Recall it)

2) COMPREHENSION (Rephrase it or Do it)

****

HIGHER THINKING PROCESSES:

3) APPLICATION (Apply it)

4) ANALYSIS (Take it apart)

5) SYNTHESIS (Put it together)

6) EVALUATION (What’s it worth?)

"BLOOM'S"
LEVELS OF UNDERSTANDING: A CONCEPTUAL PERSPECTIVE

Benjamin Bloom, as editor of a committee's work published in 1956, is honored in name as the originator of one of education's few solid foundational pillars: His taxonomy of intellectual (cognitive) skills. This taxonomy describes the increasingly complex and abstract levels at which a concept can be understood. As a brief explanation:

IDENTIFICATION/INFORMATION: The student can remember information. The memory is fairly close to the original form of the material and could be either by recall or recognition. The information could be specific facts, general concepts, propositions, procedures, or patterns. Demonstrating this level of accomplishment, students can define, identify, label, list, match, name, select, state, etc.

COMPREHENSION: The student knows the literal meaning of material without necessarily being able to relate it to a context or any other material. The student can paraphrase or summarize the material, give examples and explain how the example relates to the concept. The student understands literary devices such as simile, analogy, and metaphor. The student can also translate between verbal and mathematical or symbolic material, such as the periodic table, graphs and equations. Also included are estimation and the ability to use an algorithm to solve a problem. At the top end of comprehension, the student can compare two entities by identifying similar and different features that are on the surface or concrete as well as relevant to the concept. The student can also apply the concept to a familiar context when told to use it and the connections between concept and context are super-ficial or obvious.

↑

The "Lower" Thinking Skills

- -

The "Higher" Thinking Processes ("HOT:" Higher Order Thinking)

↓

APPLICATION: The student will apply a concept to an unfamiliar situation without previously being told what concept to use or how to apply the concept. The student can recall the relevant concept and use it to address a particular question. The student can apply science concepts to the uses and designs of technology.

ANALYSIS: The student can take material and break it down into its parts that are relevant to the concept. Furthermore, the student can identify the relation-ships between and among the parts and recognize and describe their organizational patterns. Students are analyzing when they are diagramming, concept mapping, webbing, or outlining. Another major analysis skill is deep-level comparing, where students identify similarities and differences of features they have extracted from analysis of two entities rather than from their super-ficial or concrete features.

SYNTHESIS: The student can collect, assemble, and categorize disparate material into a coherent, organized whole in a process guided by the concept, usually in concert with other associated concepts, and whose final design is shaped, either implicitly or explicitly, by a framework based upon these conceptual lenses. The result is more than the sum of the parts because the identified connections and relationships among them form a coherent, single creation focused by the concept(s). The student may produce a performance, such as a scientific investigation, poem or polemic, that involves the ability to plan and, ultimately, enact, a set of operations, that follow guidelines that are require considerable judgment and choice.

EVALUATION: The student can describe and make balanced judgments about the relevance, accuracy and importance of some material or a performance from the perspective of the concept and, most often, associated concepts, and can create a summation that is judgmental and supported in proportion to the impact of the judgment.

CREATIVITY: When addressing a question, the student can purposefully chose and orchestrate an unusual but effective combination of conceptual elements and contextual features of the question, relating them in combinations, sequences and relative weights to produce an original material or performance that is expressed through a facile fluency with the skills and processes, both inherent and communicative, best suited for creating and communicating a proposed answer to the question.

For a complete explanation of the first six intellectual skills, see B.S. Bloom, Editor. TAXONOMY OF EDUCATIONAL OBJECTIVES: COGNITIVE DOMAIN. New York: Longman Inc.. 1956. In this original publication of what has become known as Bloom's Taxonomy, these six skills are each broken down into more specific skills organized into three tiers. Although the above explanation of the six processes makes them appear discreet, a full discussion of their component skills and processes makes it clear that they are on a continuum, blending from one to the next.

The seventh intellectual skill on the list, Creativity, extends Bloom's Taxonomy, as recommended by Anderson and Krathwohl (2001) in their Taxonomy for learning, teaching, and assessing; A revision of Bloom's taxonomy of educational objectives.

These seven intellectual skills are listed hierarchically, in that each one includes the skills preceding it. HOWEVER, this logical hierarchy does NOT imply that the skills must be learned, and taught, in the numbered sequence. The optimum learning sequences are still a matter of educational research. There is good evidence that optimum learning does NOT follow the strict sequence from bottom to top. Beginning with the higher-order skills might well be a more effective route to learning component, lower-order skills than beginning on the lower-order skills and insisting on mastery before moving to the next.

CHOOSING AN APPROPRIATE LEVEL OF UNDERSTANDING

Choosing an appropriate level of understanding for the student(s) in question is an art. It involves the careful and intuitive balancing of many facets of the student(s). There are two broad categories of student factors that should be considered: the physical/cognitive, and the motivational.

The physical/cognitive student factors consider the level to which the student is CAPABLE of understanding. Specifically, factors to consider are:

1) Chronological age
2) Neurological maturity e.g. motor/coordination & intellectual developmental stage (Piagetian stages)
3) Academic ability/Learning rate.

Most students from about second/third grade on are mentally CAPABLE of exercising any of the six intellectual skills/processes. However, the upper-level processes require more patience, perseverance and concentration than the lower-order skills. Thus students might not be motivated to exercise such processes. The student factors that relate to motivation are:

4) Physical disability e.g. hearing/seeing problems, hunger, illness
5) Basic skills competency
6) Psycho-social maturity
7) Self-esteem
8) Ability to function independently.

Rather than considering each of the five upper-level processes separately, as discreet from the others, it is often more useful to see the exercise of higher-order thinking to be a fluid process in which the four processes of applying, analyzing, synthesizing and evaluating are often inter-twined and over-lain, sometimes producing a creative product or performance. With a focus on the larger-scale pattern of combining a transferable concept with a specific topic or question in whatever manner, the question of student motivation is the same for all the higher-order processes: What will it take to get the student from wherever he/she is starting to the perseverance and work habits that make higher-order thinking fluid and enjoyable?

ORGANIZATIONAL CHART OF SKILLS AND PROCESSES

Social Skills or Social Processes	Motor or Kinesthetic Skills
Examples:	Examples:
Cooperation	Drawing, diagramming, mapping
Self-management	Using instruments to measure
Listening	Keyboarding and calculator use
Communication	Using media and information technologies
Perseverance, etc.	Information retrieval

Thinking Process Skills

Problem solving
Critical thinking
Numeracy
Interpreting
Observing
Classifying
Comparing
Deduction
Induction
Note taking
Dictionary
Syllabification
Phonics
Using context clues
Using metaphors, analogies
Recognizing
Estimating
Inferring
Counting
Describing
Ordering
Organizing
Predicting
Reading charts & graphics
Hypothesizing
Drawing conclusions
Designing
Outlining
Defining
Categorizing
Questioning
Calculating
Quantifying
Displaying
Listing
Representing
Matching
Summarizing

…… can all be classified as one of Bloom's six categories of thinking skills, or, more typically, as a combination of two or more …..

Knowledge/Information:
recall, define, identify, label, list, match, name, select, state, recognize, repeat, recite, etc.

Comprehension:
paraphrase, describe, summarize, provide original examples, punctuate, estimate, translate among different representations such as charts, graphs, and maps, etc.

Basic Thinking Skills ↑

Higher Thinking Processes (i.e. Higher Order Thinking: "HOT") ↓

Application:
use analogies and metaphors, question, predict, extrapolate, classify, compare, etc.

Analysis:
deduce, take notes, interpret, conclude, outline, construct graphical organizers such as charts, graphs, maps, webs, etc.

Synthesis:
induce, generalize, infer, organize, predict, hypothesize, conclude, design, compose, etc.

Evaluation:
critique, debate, judge, rate, support, check, identify errors, justify, prioritize, etc.

TWO MAJOR SHIFTS IN THINKING ABOUT CURRICULUM

1) **THERE ARE THREE PARTS TO CURRICULUM; THREE CATEGORIES TO STUDENT LEARNING OUTCOMES:**

   A) TRANSFERABLE CONCEPT
   B) TOPIC CONTEXT
   C) SKILL

   (A and B: Combined into the Conventional category of "content")

2) THE HIGHER THINKING PROCESSES CAN ALL BE OBJECTIVELY DEFINED (AND THEREFORE ASSESSED) AS PARTICULAR METHODS OF COMBINING GENERIC CONCEPT(S) WITH SPECIFIC TOPIC(S).

Skills are the particular methods students use to combine concept with topic during instructional activities.

A DISCUSSION ON THE NATURE OF CONCEPTS

This activity is dedicated to an open discussion focused on the nature of concepts. You have been introduced to a concept-based model of curriculum. At this point it might be helpful to have an open discussion that would include your prior impressions of the nature of concepts, your classroom and/or administrative experience with concepts, and how these two mesh with what you have learned so far in this workshop. The free exchange of opinions, insights and experiences should help everyone gain a deeper appreciation for the nature of concepts.

ASSIGNMENT:

- Choose one subject areas (science, math, social studies, language arts) and attempt to identify one or two concepts that everyone in the group feels confident are bona fide. Then choose one of the following four perspectives to begin your conversation.

- Allow the conversation to move into one of the other perspectives, into other subject areas and/or concepts, or even into original territory.

- Have one group member keep rough notes of the conversation in order to report out to the entire group.

FOUR POSSIBLE PERSPECTIVES:

A) What are the concepts that underlie a subject area? What are the concepts that would be useful to a student learning the subject? Can these concepts be clearly distinguished from specific topic information or skills? Are the concepts also useful in other subject areas?

B) What is the definition of each of the concepts? Are different terms being used for the same concept? Is it possible to distinguish the minimum, essential attributes of the concept from the embellishing, expanding attributes? How is the definition useful to assessing the degree to which a student has learned it?

C) Where/How are the concepts useful for teaching and learning about specific topics? How easily "transportable" are the concepts among widely varying topics? Can you think of many different ways that a student could combine a particular concept with a particular topic?

D) How can a curriculum that distinguishes betwen concept, topic and process/skill motivate both students and teachers? How can the different interests, skill levels and backgrounds of students be accommodated? How can teachers rely upon their strengths while broadening their own knowledge and skills? How is the relationship between teacher and student affected?

DEFINING CONCEPTS:

The simplest concepts are defined in terms of examples taken from direct observation and experience. For example, the concept of COLOR is defined by listing many examples of colors, and the student then forms the concept by generalizing from the examples.

Complex concepts can be defined in terms of other, simpler concepts. Try to focus on the ESSENTIAL attributes of the concept. So ECONOMY might be defined in terms its essential attributes of PRODUCTION, DISTRIBUTION and CONSUMPTION, each of which might in their turn be defined in terms of their own essential attributes.

WHAT ARE THE BASIC CONCEPTS OF SCIENCE?

There are two types of ideas in science. The first type is TOPICS. It is information and facts. For example, you could study the topic of insects. You could study the planet Earth, learning the fact that it orbits the sun in 365.25 days. There are an infinite number of topics and facts. The fields of science (such as geology, chemistry, psychology, medicine, etc.) are often used as ways of dividing up and categorizing topics. So somebody who knows a lot of facts about the stars knows about astronomy.

The second type of idea in science is called a CONCEPT. Concepts are general, key ideas that apply to a large, large number of topics. Concepts are the key ideas used to understand, remember and enjoy the infinite number of facts. There are only a small number of concepts. You only have to learn a small number of key concepts to understand ANY and ALL the infinite topics.

The most general, all-inclusive concepts are called BASIC concepts or FUNDAMENTAL concepts. Basic concepts apply to a very wide variety of facts. Basic concepts are like master keys because they open up lots and lots of different information. There are other concepts that are still key ideas, but only open a smaller amount of information. For example, the LANGUAGE OF SCIENCE is a basic, fundamental concept because it applies to any and every entity in the natural world, from galaxies to pin-heads to atoms to sounds to rainbows. REFLECTION is also a concept, but it only applies to things like basketballs and waves like light or sound that happen to be bouncing off of something.

There are six basic, key-idea physical concepts and six basic, key-idea life concepts. The physical concepts apply to non-living things as well as living things if their life processes are not important. The life concepts deal with the processes of life. Some questions about non-living things are also best addressed with the life concepts. All twelve of these basic concepts can apply to either living or non-living things.

PHYSICAL CONCEPTS	LIFE CONCEPTS
THE LANGUAGE OF SCIENCE	INTERDEPENDENCE
ENERGY	GROWTH
WAVES	REPRODUCTION AND HEREDITY
CHEMICAL REACTION	EVOLUTION
MOTION AND FORCES	REGULATION
ELECTRICITY AND MAGNETISM	BEHAVIOR

Each of the twelve basic concepts can be divided into "smaller," more specific concepts. Much of your science education will consist of learning the parts of each basic concept. However, these more specific concepts become quite easy to learn if you see them as parts of the bigger, most basic concepts listed above. The magic of science is that ALL the infinite number of questions that could be asked can be answered with only twelve basic concepts. Since asking and answering your own questions is intensely fun, these twelve ideas can be a source of great enjoyment to you. Also, most jobs today require people to understand these basic, fundamental ideas and apply them to all sorts of questions and problems. Most jobs tend to use some of the basic concepts more than others, but you will be prepared for any job by learning to understand all twelve.

For example, many people are interested in whales and porpoises. You would need to know about INTERDEPENDENCE to answer questions about why whales live in packs. You would also need to know about WAVES to answer questions about how whales can produce their peculiar sounds and communicate over hundreds of miles of ocean. You might ask questions about how whales can dive quickly to incredible depths. Then the basic physical concept of MOTION AND FORCES as well as the life concept of REGULATION become important. They are both useful for understanding how the whale can quickly change its body functions to withstand the pressures deep in the ocean that would kill any other mammal, including humans.

These twelve basic concepts are big ideas that you already know quite well. Your everyday experiences start you with a good understanding of these twelve big ideas. Below are brief descriptions of each.

There is one category of questions that cannot be easily answered by any one of the twelve basic concepts. This is the TECHNOLOGY category. There are some questions, such as, "How does a car work?" that require more than one of the basic concepts for an answer. Technology questions usually require you to combine three or more basic concepts for an answer. If you ask, "How can we produce clone animals?" the answer requires more than one of the six basic concepts of the life sciences.

PHYSICAL CONCEPTS

1) LANGUAGE OF SCIENCE: - Identifying and naming things: What is it??
- Describing things in terms of their physical properties like size, shape, composition, number, phase, temperature, texture, density, etc..
- Describing the changes in physical properties during a process or event: What happened?

EXAMPLE QUESTIONS:
A) What is a galaxy? B) How hot is the sun?
C) Is shark skin smooth if you rub it in one direction and rough if you rub it in the other?
D) Does fog come from the ground or from the air?
E) How did the planets form?

---

2) ENERGY: - Describing how things contain energy, like a speeding bullet, a firecracker, a stretched rubber band, a big meal, boiling water, falling water, X-rays, etc..
- Describing how some materials are fuels, foods, or explosives.
- Measuring energy as it flows from one thing to another.
- How heat flows from one thing to another, through conduction, convection and radiation.

EXAMPLE QUESTIONS:
A) How big a bomb could blow up the world?
B) How come gasoline is a fuel but water isn't?
C) Why does sunlight heat you up?
D) Why are X-rays dangerous to you?
E) If you put bigger batteries in a toy, will it run faster?

3) WAVES: - Describing the four types of waves: sound, light, water waves, and vibrations. (light includes all types of radiation, such as ultra-violet, infra-red, radio and TV waves, X-rays, etc.)
- Describing the behavior of waves, like how they move, how they are reflected (bounced), how they bend and focus.
- Describing how waves are produced, absorbed and travel through materials.

EXAMPLE QUESTIONS:
A) What's the difference between music and noise?
B) Why do some ocean waves break when near shore?
C) How come your reflection is upside down in a spoon?
D) Why do people sound so good singing in the shower?
E) How does a magnifying glass focus sunlight?
F) Why can I feel vibrations so well lying in bed?

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4) CHEMICAL REACTION: - Describing how the composition of a thing or substance *changes*. (Composition is what a thing is made of.) Composition changes when a thing's color, taste, or smell changes.
- Chemical reactions like explosions, burning, rotting, acid and alkalis eating materials.

EXAMPLE QUESTIONS:
A) Why does heating an egg make it turn white?
B) Why do dead animals smell?
C) How does gunpowder explode?
D) How does a fire extinguisher put out a fire?
E) How does our body digest food?

---

5) MOTION AND FORCES
- Describing how things move or seem to move, with ideas like speed, velocity, and acceleration.
- Forces & pressures, like push, pull, balance, friction, gravity, strength, breaking things, making things move, stay put, or change shape.

EXAMPLE QUESTIONS:
A) If you dropped a penny from the World Trade Center, how fast would it be going when it hit the sidewalk?
B) Why doesn't a roller coaster come off the track when it goes upside down?
C) What pressure do you need to turn coal into diamond?

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6) ELECTRICITY AND MAGNETISM
- Describing static electricity, sparks, shocks.
- How electrical conductors and insulators work.
- How wires, motors, bulbs and electronics work.
- How magnets, compasses, and magnetic fields work.

EXAMPLE QUESTIONS:
A) How do you get sparks from electricity?
B) How can magnets stick to metal that isn't magnetic?
C) Why are there magnets in electric motors?

LIFE CONCEPTS

1) INTERDEPENDENCE: - How organisms (plants and animals) depend upon each other and affect each other in their regular lives and for their survival.
- How organisms depend upon their physical environment in their regular lives and for their survival.
- All organisms exchange materials with their environment, changing ingested substances into excreted ones.

EXAMPLE QUESTIONS:
A) Why aren't there any salmon in the Connecticut river any more?
B) Does sugar water really make pumpkins grow bigger?
C) Where do rabbits find food in the winter?
D) How does pollution kill forests?
E) Do all plants needs sunlight to survive?
F) Do animals urinate as much water as they drink?
G) Do animals extract ALL the oxygen from each breath, or is some oxygen still left when they breath out?

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2) GROWTH: - How an individual organism is born, grows, develops or dies.
- Describe radical changes in an organism like metamorphosis, puberty, seed germination, flowering, fruiting, etc., during which it becomes a different thing.

EXAMPLE QUESTIONS:
A) Why do babies often have big heads?
C) How can lizards grow back their tails?
D) How can a caterpillar turn into a butterfly?
E) How does an apple blossom turn into an apple?
F) How do steroids make big muscles?
G) Do all animals stop growing before they stop living?
H) Why do trees keep getting thicker but eventually stop getting higher?

---

3) REPRODUCTION AND HEREDITY - How all organisms and cells produce new, young organisms as offspring.
- How the traits of parents are passed on to the young.
- How the cell's genetic material (DNA, etc.) dictates an organism's traits.

EXAMPLE QUESTIONS:
A) Why do children look like their parents, but aren't exact copies?
B) How come any two kinds of dog can have puppies, but dogs can't have babies with cats?
C) If my grandmother had cancer, will I get cancer?
D) How does the DNA from two parents mix together in their child?

4) EVOLUTION: - How species change from generation to generation, even becoming extinct.
- How species have changed to adapt to their environment.
- How species change because changes in their offspring are better or worse for surviving in their environment.
- How the molecules and cells that make up all organisms also change over time from generation to generation.

EXAMPLE QUESTIONS:
A) Why do people have toes?
B) Why did dinosaurs disappear?
C) Where did people come from?
D) Why do birds have different shaped beaks?
F) Did humans first develop the ability to walk or the ability to talk?

---

5) REGULATION: - How life processes (respiration, digestion, movement, etc.) operate, affect each other, and are controlled.
- How the senses and feelings (pain, hunger, cold, etc.) control life processes.
- How health and disease are caused by a balance or imbalance in the life processes.
- How organisms acquire, store and use energy to keep their life processes going.

EXAMPLE QUESTIONS:
A) Why do tears form when you cry?
B) How do you get stronger by lifting weights?
C) What makes men's beards grow?
D) How can vaccinations prevent disease?
E) How do plants use sunlight to build themselves from water and carbon dioxide?
F) Can an animal be both warm- and cold-blooded at the same time?

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6) BEHAVIOR: - How organisms respond to short-term or surprise changes in the environment or actions by other organisms, usually by moving or changing shape.
- How animals have instinctive patterns of behavior.
- How animals communicate, learn, or interact in groups.

EXAMPLE QUESTIONS:
A) Why do animals run away when they are scared?
B) How do tulips open and close from night to day?
C) Why do insects such as ants live in colonies while others don't?
D) Why do groups of whales sometimes beach themselves?
E) Why do wolfs hunt in packs?
F) How do birds know when to migrate?

TASK: CATEGORIZING QUESTIONS ACCORDING TO THE 12 BASIC CONCEPTS OF SCIENCE

INTRODUCTORY TASK:

What concept(s) would be most useful when learning about:

cars: ______________________________
cells: ______________________________
dynamite: ______________________________
mountains: ______________________________
trees: ______________________________

MAJOR THESIS STATEMENT ABOUT CONCEPTS:

____

PRIMARY TASK:

You were asked to come up with five different questions about the natural world around you; Questions that express your curiosities about what you see and experience in your daily life. Write these questions below.

1) ______________________________

2) ______________________________

3) ______________________________

4) ______________________________

5) ______________________________

For each of the questions, decide which of the 12 basic concepts of science would be most useful for addressing the question. Use the accompanying short text definitions for help.

QUESTION	MOST USEFUL CONCEPT

GOOD CURRICULUM DESIGN DEPENDS UPON A CONCEPTUAL STRUCTURE

"Good curriculum design requires an analysis first of the concepts in a field of knowledge, and, second, consideration of some relationships between these concepts that can serve to illuminate which concepts are most general and super-ordinate and which are more specific and sub-ordinate. One reason that school instruction has been ineffective is that curriculum planners rarely sort out the concepts they wish to teach and even more rarely do they try to search for possible hierarchical relationships among these concepts...

"The central point is that efficient learning of concepts requires explication of relationships between concepts and progressively greater development of the most salient concepts... The identification of frameworks of concepts is fundamental and must precede curriculum planning... Instruction (is), in essence, dependent upon the extent to which the concepts developed by (professionals in the field) become the concepts of students' cognitive structures...

"If we cannot identify salient concepts in a field of study, distinguish among concepts, and isolate relatively trivial or subordinate concepts, curriculum planning is likely to proceed from a list of topics, such as one finds in the table of contents of most books. Sometimes topics are also concepts, for example, "Cells - Structure and Function" or "Mercantilism," but more often they represent a conglomeration of concepts, perhaps with some logical coherence but without psychological organization. In other words, in topically organized instruction, we often cannot show how the learning sequence would facilitate hierarchical ordering of concepts."

(J. Novak, 1977, A Theory of Education)

TASK:

Relationship, hierarchy, order, structure; All require some standard(s) or parameter(s) upon which to judge the relative placement of items. If concepts are to be organized in a hierarchical ordering, what characteristics of transferable concepts could be used as parameters to construct such a conceptual structure?

*Another way to think of this is to ask, "What are the differences between and among concepts other than what they mean?"*____

____

After identifying a characteristic, attempt to define it and/or give illustrative examples.

ALL TRANSFERABLE CONCEPTS DIFFER IN THREE WAYS

THAT MATCH THE COGNITIVE DEVELOPMENT OF STUDENTS :

1) GENERALITY.
How wide a variety of questions, topics, situations does it apply to?

Students learn from:

GENERAL/ OBVIOUS ⟶ **SPECIFIC/ SUBTLE**

(e.g. Porosity   Permeability)

****

2) COMPLEXITY.
How many ideas does the student keep in mind <u>simultaneously</u> ?

Students learn from:

SIMPLE ⟶ **COMPLEX**

(e.g. Speed   Acceleration)

****

3) ABSTRACTNESS.
How far from direct sensation and perception is the concept?

Students learn from:

CONCRETE/ OBJECTIVE/ TANGIBLE ⟶ **ABSTRACT/ SUBJECTIVE/ INTANGIBLE**

(e.g. Temperature   Area)

The Basic Concepts of Science

LANGUAGE of SCIENCE

INTER-DEPENDENCE

ENERGY

WAVES

GROWTH and DEVELOPMENT

BONDING

REPRODUCTION, HEREDITY

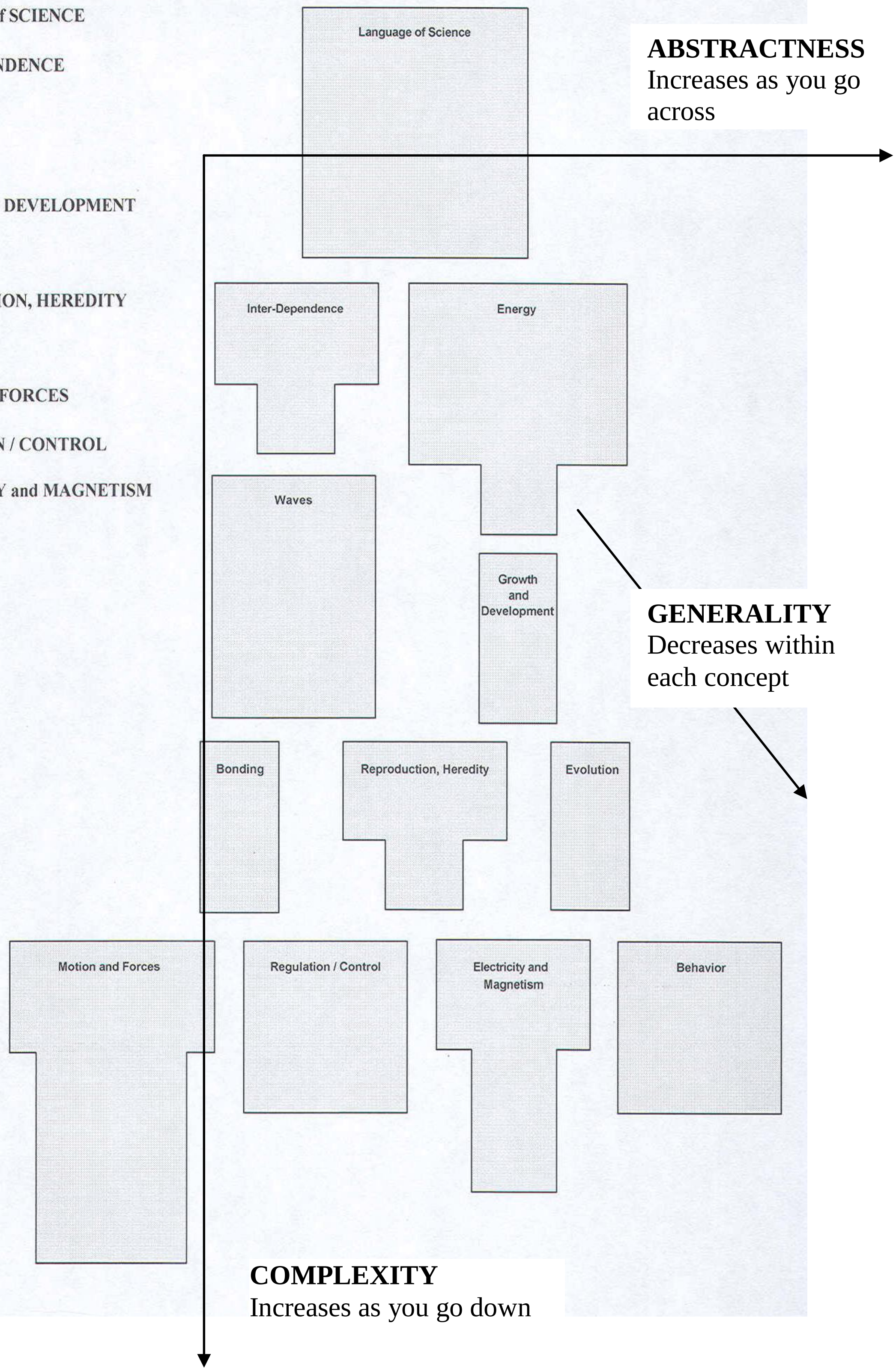
EVOLUTION

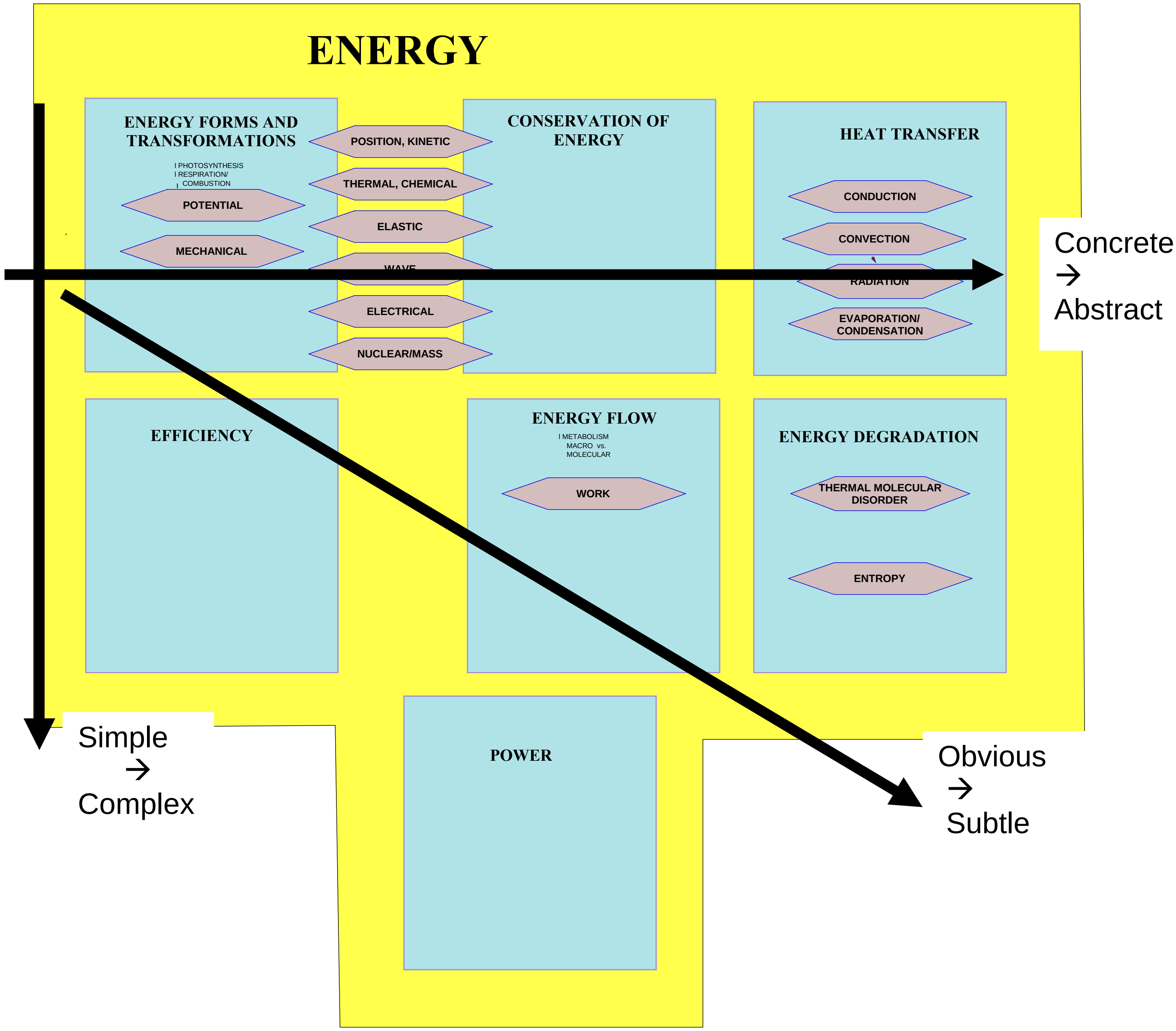
MOTION and FORCES

REGULATION / CONTROL

ELECTRICITY and MAGNETISM

BEHAVIOR





Each of the twelve major concepts, or trunks, of science can itself be broken into sub-concepts, and each of those into further sub-concepts. The resulting lists of sub-concepts can themselves be organized according to generality, complexity, and abstractness.

IV

- **CONCEPTUAL STRUCTURE FOR SCIENCE**
- **WRITING GENERALIZATIONS**
- **GENERALIZATIONS FOR SCIENCE**

MASTER STRUCTURE of TRANSFERABLE CONCEPTS FOR SCIENCE

UP-DATED: 2-25-12

KEY: SLASH: major synonyms
COMMA: closely linked, synergistic concepts
BULLET: other synonyms and common associations

SEQUENCE LETTERS:
- A before B before C, etc.
- capitals indicate an essential concept
- lower case indicates could be skipped
- same letter indicates that order doesn't matter

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
LANGUAGE OF SCIENCE A • nature of matter • pattern language	ENTITY A • things and substances (intensive, extensive properties) • delineation, naming • wave • system • environment, context	SCALE/SIZE A • Levels of organization
		NUMBER B
		PHASE, STRUCTURE B
		COMPOSITION, CONCENTRATION B
		TEMPERATURE B
		MATTER C • elements, compounds, mixtures • kinetic theory of matter • Periodic table • radioactivity
	PROPERTY/MEASUREMENT A • observation, value, unit • error, accuracy • misc properties: hardness, melting/boiling T^{o}'s, (non)-conductor	SCALE/SIZE A
		NUMBER B
		PHASE, STRUCTURE B
		COMPOSITION B
		TEMPERATURE B
		DISTANCE, AREA, VOLUME C • dimensions
		SHAPE, ANGLE, CONFIGURATION c
		SPEED C
		LOCATION, DIRECTION, ORIENTATION c
		TEXTURE d
		HARDNESS, CLEAVAGE d
		POROSITY, PERMEABILITY E
		MASS F
		DENSITY, CONCENTRATION G
		UNIFORMITY h
		CHARGE, POLARITY h
		SOLUBILITY h
	CHANGE/ PROCESS B	RATIO, PERCENTAGE A
		SEQUENCE of EVENTS, TIME, RATE A
		CYCLE B • input-output • dynamic equilibrium
		CORRELATION, CAUSALITY B (in)dependent, controlled variable
		GRAPH, EQUATION B

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
INTERDEPENDENCE/ ECOSYSTEM B • predator/prey • food chain/web • symbiosis: parasitism, commensalism, mutualism • natural and mechanical systems	NATURAL ENVIRONMENT A • surroundings, context • biome	HABITAT, NICHE A
		RESOURCE, POLLUTANT A
		DESIGNED or CONSTRUCTED ENVIRONMENT b
		CONSERVATION, RESTORATION B
	DIVERSITY A • community	SPATIAL , TEMPORAL DISTRIBUTION B
		STATISTICAL DISTRIBUTION b • Normal (bell) distribution
	COMPLEMENTARITY B	FORM AND FUNCTION A
		CARRYING CAPACITY (NATURAL LIMITS) A
		SUCCESSION, CLIMAX a
		CYCLE B

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
ENERGY B • energy resources and uses	ENERGY FORMS & TRANSFORMATION A • groupings: potential, mechanical • photosynthesis • metabolism/respiration	POSITION (GRAVITATIONAL) ENERGY, KINETIC ENERGY A • mechanical energy
		THERMAL, CHEMICAL ENERGIES A
		ELASTIC ENERGY A
		WAVE ENERGY B
		ELECTRICAL-MAGNETIC ENERGY B
		NUCLEAR/MASS ENERGY B
	HEAT TRANSFER a	CONDUCTION A
		CONVECTION A
		RADIATION B
		ADVECTION b • transfer thru latent heat
	CONSERVATION OF ENERGY B	
	EFFICIENCY C	
	ENERGY FLOW, WORK C • bulk flow vs. molecular flow	
	POWER D	
	ENERGY DEGRADATION d	ENTROPY A • molecular disorder • 2nd law of thermodynamics

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
WAVES C • representation • type/media: surface, sound, light/radiation, vibration • properties: wavelength, frequency, amplitude, speed, direction, energy	PRODUCTION, ABSORPTION, PROPAGATION A • color of things and substances • transverse, longitudinal, polarized waves • perception • spectra	INTERFACE A partial reflection, transmission, absorption
		SUPERPOSITION, INTERFERENCE, RESONANCE B
		DOPPLER EFFECT C • shock wave, wake
	REFLECTION, FOCUS A • luster/sheen • specular, diffuse reflection	SCATTERING a
	REFRACTION B • Snell's Law • Lenses • total internal reflection	DISPERSION a
	DIFFRACTION c	WAVE-PARTICLE DUALITY a

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
GROWTH, DEVELOPMENT C	STAGE/PHASE A • embryo, infancy, childhood, adolescence, adult, elder • life cycle	GENESIS A
		MATURATION A
		METAMORPHOSIS A • molting
		DEGENERATION, SENESCENCE a
		REGENERATION b
	DIFFERENTIATION, SPECIALIZATION B	
	LINEAR, EXPONENTIAL, GEOMETRICAL INCREASE B	

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
CHEMICAL REACTION D • reactants, products • number/mass/volume/soln stoichiometry • synthesis/decomposition • single/dbl displacement • acid/base, neutralization • redox, combustion • organic reactions	BONDING A • octet rule • ionic/covalent bonds • molecular structure (Lewis, VSEPR) • inter-molecular forces (dipole, hydrogen, metallic and dispersion bonds) • solvent-solute interaction	
	CHEMICAL ENERGY, THERMAL ENERGY b • thermochemistry • sensible, latent heat • ionization energy, bond energy • heat of reaction, heat of formation • activation energy, exo/endothermic reactions • Hess's Law	ENTROPY, FREE ENERGY a
	KINETICS b • catalyst	CHEMICAL EQUILIBRIUM a • Le Chatelier's principle

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
REPRODUCTION, HEREDITY D • inherited traits • dominant/recessive traits • Punnett squares • succession, pedigree	SEXUAL, ASEXUAL REPRODUCTION A • cellular reproduction	
	FERTILITY, FERTILIZATION a • pollination • ovulation, menstruation	
	GENETIC CODE, CODE B • genetic variation, gene/allele	TRANSLATION A ▪ transcription, replication ▪ RNA functions
		TRANSMISSION b
		EXPRESSION B • epigenetics
		MUTATION b • genetic drift • environment affects

BASIC CONCEPT		SUB-CONCEPT		SUB-SUB-CONCEPT	
EVOLUTION	D	SELECTION • natural selection • sexual selection • forced selection	A	VARIATION, ADAPTATION	A
				EXTINCTION	A
		SPECIATION • convergence • co-evolution	B	GENETIC CODE (CODE)	a

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
MOTION, FORCES E • types of motion (ir/regular, repetitive, accelerated, etc.) • interaction • types of forces (contact, gravity, elastic, electro-magnetic, etc.) • gravity, weight, mass	VELOCITY, DISPLACEMENT A • Displacement versus path distance • speed plus direction	FRAMES OF REFERENCE b
		SPECIAL RELATIVITY c
	FORCES, NET FORCE, NEWTON'S 3RD LAW A • types of forces • force vector manipulation: scaled diagram, components	FRICTION A
		GRAVITY A • Universal gravitation
		ELECTROSTATIC FORCE b
		TORQUE, CENTER OF GRAVITY b • balance
		PRESSURE b • tension, compression • shear • lift • static fluid forces
		STRENGTH c • stress, strain
	FLUID FLOW a	LAMINAR FLOW, TURBULENCE A • current, streamlines
		BOUNDARY CONDITIONS b
	ACCELERATION, NEWTON'S 2ND LAW B • kinematics • linear dynamics • impulse-momentum	FICTITIOUS FORCE a • Accelerated frames of reference • Coriolis force
	2- & 3-DIMENSIONAL MOTION C • vectors for d, v, & a • central force, universal gravitation	PROJECTILE MOTION A
		CIRCULAR MOTION B
		HARMONIC MOTION b
	CONSERVATION OF MOMENTUM C	
	ROTATIONAL DYNAMICS d • angular motion properties	CONSERVATION OF ANGULAR MOMENTUM, ANGULAR ENERGY A
		ROLLING b
	QUANTUM MECHANICS e	

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
REGULATION (CONTROL) E	SWITCH A • trigger	
	FEEDBACK A • positive, negative feedback • connectivity	
	EQUILIBRIUM B • homeostasis • health	RESTORING MECHANISM A
		SUSTAINABILITY a
		THRESHOLD, CRITICAL MASS b • tipping point
	DISEASE, MALFUNCTION B • abnormality	CONTAGION VECTOR A • propagation of disorder
		EPIDEMIC a
		ADDICTION b

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
ELECTRICITY, MAGNETISM E • charge, polarity • conductors, insulators • attraction/repulsion • mapping elec & mag fields	SIMPLE CIRCUIT, OHM'S LAW A • load, source/supply • current, resistance, voltage • open circuit, short circuit • alternating and direct current	
	CONSERVATION OF CURRENT, VOLTAGE b • Kirchoff's Laws • series, parallel, combination circuits	CONTROL MECHANISM a • relay, diode, transistor/gate, integrated circuit, transformer
	ELECTRIC FORCE FIELD, ELECTRIC POTENTIAL c • Coulomb's Law; Inverse square law	GAUSS'S LAW a • line of force • flux
		CAPACITANCE b
	MOTOR, GENERATOR c	
	MAGNETIC FORCE FIELD d • Force on moving charges • Bio-Savart law	AMPERE'S LAW a
		ELECTROMAGNETIC INDUCTANCE b • Lenz's Law • magnetic flux • transformers • AC inductance
		FARADAY'S LAW c • (Self-) inductance
		LR, LC, LRC CIRCUITS d
		MAXWELL'S EQUATIONS d

BASIC CONCEPT	SUB-CONCEPT	SUB-SUB-CONCEPT
BEHAVIOR E • stimulus-response • classical, operant conditioning • survival, self-interest, cooperation • nature vs. nurture	INSTINCT A	MATING A • female choice
		AGGRESSION A
	COMMUNICATION A	PERSUASION a
	LEARNING b • memory • language	COGNITION A • Accommodation, Assimilation, Adaptation • Thinking and reasoning
		KNOWLEDGE TRANSFER B • higher-order thinking • problem solving, decision making
		MOTIVATION, EMOTION b • curiosity • hierarchy of needs
		COMPETENCE, INTELLIGENCE c
	PERSONALITY b	ALTRUISM b • reciprocity
	STATES OF CONSCIOUSNESS c • sleep and dreams • hypnosis, meditation • drug induced	

GENERALIZATIONS DEFINE THE TRANSFERABLE CONCEPTS

Generalizations are also known as enduring understandings, big ideas, or principles. A transferable concept is defined by its generalizations – without defining generalizations a “concept” becomes a vocabulary term with a dictionary definition. Generalizations precisely define the knowledge that students are to learn when they learn the transferable concept. Therefore generalizations are the connection to objective assessment of conceptual understanding. Generalizations are the machinery that connect curriculum, instruction and assessment to produce higher order learning in your students.

The generalizations for each of the science concepts can be found within The Curriculum Library. The Library’s extensive option tree of educational criteria is used to specify the type of curriculum resource (lesson) that you are looking for. If you explore the COURSE OR CONCEPTS branch of options, the HELP icon for each concept leads to a page that gives the generalizations for that concept.

The HELP page for each concept also has a prominent button that connects you with a forum for making and exchanging suggestions for generalizations with other educators. These forums are also the venue for discussing the placement of the concept within the overall conceptual structure, the definition of the concept, and the translation of the generalizations to student-friendly language as well as to other languages than English.

The generalizations for all of the concepts are not collected and available in one document to avoid the impression that they are immutable. The generalizations are presented as starting points with the hope that they will evolve and improve with many different people’s help.

BACKGROUND NOTES:

1. Generalizations are **also called enduring understandings** or principles. Sometimes they are referred to as “big ideas,” although this term is more often and more accurately understood as a synonym for a transferable concept.

2. **A generalization is a propositional statement expressed as a conclusion** that links the subject concept (the subject of the generalization) to one or more other transferable concepts. Generalizations (different from dictionary definitions that describe common usage) are intended to encapsulate the knowledge that would constitute an understanding of the concept. What do you know if you understand this concept? Generalizations are generally one sentence since a sentence is, by definition, a complete and coherent structure of logical relationships.

3. **Generalizations define transferable concepts**, so every generalization “belongs” to a transferable concept which is the subject of the generalization. This document is organized according to the master conceptual structure for science. The font sizes and indentations of

the headings represent the three levels around which this master conceptual structure is organized.

4. The **intended audience** for these generalizations **is the teacher**. Teachers will usually need to translate a generalization into suitable expressions for student use depending upon the instructional situation.

5. Generalizations are the primary **links between curriculum and assessment** of conceptual knowledge. A rubric for assessing the degree of understanding of a particular concept would be based upon its generalizations.

6. The generalizations presented here are intended to define the "minimum criterial attributes" of each concept – **what is the necessary and sufficient knowledge required to form a coherent, unitary, and reasonably useful transferable concept?** However, many of the concepts are defined liberally, with generalizations being included that some people would consider enriching more than essential. The dotted line between essential and enriching is sometimes a matter of debate, and teachers must decide where to draw these dotted lines depending upon their students and learning situation. (See PROPERTY or PROCESS generalizations for examples of such a delineation.)

In any case, the life-time growth of a person's knowledge of a particular concept can be described by an increasing number, subtlety, and complexity of connections with other concepts. These enriching connections are created through experience using the concept and related concepts in different contexts. Since every person's experiences are unique, each person's eventual, mature understanding of a concept is also unique. Yet all people share a common, foundational understanding that the generalizations in this document are intended to capture.

WRITING GENERALIZATIONS

The understanding that underlies a transferable concept can be defined with generalizations. At the first plateau of understanding, where transfer is halting or rudimentary at first, the generalizations form a set that describes the minimum essential understandings needed to form a coherent concept that provides insight to questions taken from a variety of topics/contexts. Subsequent learning will embellish and deepen understanding, as expressed in additional generalizations.

A generalization …

A. is also called an enduring understanding, basic principle, core knowledge, big idea.
B. is a propositional statement that links two or more concepts, sometimes includes specific contexts or topics, and is stated as an assertion or conclusion.
C. is widely applicable and generic as well as timeless.
D. is a statement of a fundamental aspect of the concept vital to generating insight to questions (i.e. to its understanding).
E. can be combined with specific topics or contexts to generate "essential questions."
F. links to assessment: Rubrics for conceptual understanding are based on the generalizations.
G. is not a definition in the dictionary sense of describing common usage.

PROCEDURE

A. Begin with the concept and as many of its synonyms as possible.
B. Locate the concept within the conceptual structure. List the most important surrounding concepts that contribute to its meaning.
C. Collect core information, definitions, and descriptions of the concept from as many sources as possible: brainstorming, textbooks, glossaries, experts.
D. Synthesize the concepts and information into propositional statements. Start by choosing a related concept (from your list generated in (b)) and write a sentence that connects the two.
    - ❑ avoid proper names and personal nouns
    - ❑ use active, present-tense verbs to state a conclusion
    - ❑ use terms such as "often," "most," and "may" if the generalization does not cover all possible situations or contexts
    - ❑ Ask "How" or "Why" questions.
E. Edit the statements so that there is only one generalization for each proposition. i.e. Collapse together statements that say the same thing but in different words.
F. Edit the statements to make them applicable to as wide as possible a variety of questions, topics, or contexts.

RUBRIC

LOWER ORDER ⟶		HIGHER ORDER
❑ Is largely a definition of usage; uses the verb "to be" (is, are …). ❑ Includes specific peoples, places, things; does not transfer easily or widely. ❑ Is an obvious or vacuous statement: "So what?" Relevant questions would be trivial or vapid. ❑ A student could demonstrate understanding relying on common knowledge and everyday experience. ❑ The assessment would elicit little problem solving, critical thinking, or knowledge transfer.		❑ Transcends facts while being applicable to factual contexts ❑ Transfers easily and widely ❑ Is complex, and subtle; Implies informed, strategic observation, analysis and synthesis as well as judgement ❑ Relevant questions would challenge thinking, be open-ended, imply several different "answers," involve extended investigation, inquiry, or discussion. ❑ A student would be unlikely to succeed on a performance assessment without demonstrating deep understanding.

WHAT'S THE DIFFERENCE BETWEEN THESE TWO GENERALIZATIONS?

The following two generalizations were suggested for the concept of *Carrying Capacity* within the more general concept of *Interdependence*. The group that was working together to create generalizations was discussing the conceptual difference between these two statements and how to incorporate that difference, if any, into a final set of generalizations that they could all teach to.

Imagine that you are this group and that you are attempting the same task of comparing and possibly synthesizing these two generalizations. Come to a group consensus (if possible) on how to deal with these two suggested generalizations. Be prepared to report on your group's discussion and final recommendation.

> An ecosystem can support up to a maximum population of a particular organism (i.e. its carrying capacity for that organism), depending upon the maximum flow rate of energy and/or material that it can supply to or absorb from that population.
>
> Within a stable ecosystem, the rate of exchange of materials and energy between a population and the environment (both physical and organic) is limited by the ecosystem's capacity to supply and absorb the flows.

DISCUSSION NOTES AND THE GROUP'S RECOMMENDATION(S):

COMBINING CONCEPTS TO FORM GENERALIZATIONS

Concepts exist within a web of connections to other concepts and are largely defined by those connections. This inherent connectivity of concepts contrasts with the inherent isolation of facts from each other. This connectivity of concepts is also largely responsible for their rapid recall and long-term retention once learned to a "critical mass" level where effective transfer can first occur.

The simplest, most concrete transferable concepts (e.g. temperature, shape, conflict, diction) are defined in terms of direct experience and sensory observation. More complex concepts (density, proportion, taxation, parody) are definable in terms of other, simpler concepts as well as more general, super-ordinate concepts. Generalizations, also called over-arching or enduring understandings, are propositional statements that describe the relationships between and among two or more concepts. Thus generalizations define concepts by their connections to other concepts.

ASSIGNMENT:
Choose four concepts from the conceptual structure for a particular domain of knowledge. Choose at random or choose four that, on first impression, might seem related. Write these four concepts into the boxes below:

Choose one of the concepts to be the focus or subject of the generalization:

Subject:

Drop one of the original four concepts. Write in the other two:

Write a propositional statement expressed as a conclusion focused on the one you chose as the subject. The statement describes the relationship(s) among the three concepts.

Some generalizations encapsulate the concept's essential criterial attributes that together are necessary and sufficient to activate initial transfer. Once initially formed, all concepts are enriched throughout life and later learning with additional, supplementary understanding and insight. Every person eventually forms a unique understanding based on an initial understand that is shared by all. Mark the below continuum to indicate the degree to which the above generalization is essential to a beginning, operational understanding of the concept or, at the other end of the continuum, describes supplementary or enriching understanding that could result from later learning.

Necessary for initial activation ←→ Enriching and supplementary. Creates sophisticated, rapid, or nuanced transfer.

DISCUSSION: "Back-loading" of conceptual knowledge is a major advantage of concept-based education. "Back-loading" reinforces and enhances knowledge of previously learned concepts. Similarly, many concepts foreshadow others, usually ones that are more specific, subtle, abstract or complex. Foreshadowing anticipates and prepares the path for future learning. Discuss in your group why and how back-loading and foreshadowing occur, and contrast it with topic-based instruction.

GENERALIZATIONS

DEFINING

TRANSFERABLE SCIENCE CONCEPTS

The generalizations for each of the science concepts can be found in The Curriculum Library (curriculumlibrary.com). The Library's option tree is used to specify the type of curriculum resource (lesson) that you want. If you explore the COURSE OR CONCEPTS branch of options, the HELP icon for each concept leads to the generalizations for that concept.

The HELP menu for each concept also has a prominent button that connects you with a forum for making and exchanging suggestions for generalizations. These forums are also the venue for discussing the placement of the concept within the overall structure, and even the definition of the concept.

V

THE FOUNDATION CONCEPT:

THE LANGUAGE OF SCIENCE

PRE-ASSESSMENT PROMPT – LANGUAGE OF SCIENCE

Responses are evaluated for the author's command of the following concepts:

Third Grade: *Language of Science*; **Property; Phase**

Fifth Grade: *Language of Science*; **Change/Process**

Seventh Grade: *Language of Science*; **Change/Process**

Ninth Grade (Earth Science): Language of Science; **Change/Process**

The following prompt should work for all four grade levels:

> Imagine that you are a weather reporter for your local television station and you are on the late-night news describing the previous day's weather. The day started out beautiful but then changed and became terrible, so you have lots to describe.
>
> In the space below, first describe the beautiful weather at the beginning of the day. Then describe the changes that happened. Finally, describe the terrible weather at the end of the day.
>
> Make your descriptions as clear and factual as possible, the way a weather reporter would. Use three paragraphs, one for each stage of the day's weather.
>
> If you would like (but it is not required) you may draw diagrams for one or more of the stages. Your diagrams must be titled and labeled with as much information as possible.

DESCRIBE THE VARIETY OF SPONGES

You have been given a set of many different kitchen and bath sponges. Your task is to describe the variety of the sponges; their specifics as well as their differences and similarities. You must create both a scheme for describing the sponges and a paper-based format to present your scheme to the rest of the group.

The scheme and format must illustrate and encompass:

a. the particular features of the specific sponges that you have been given
b. the differences and similarities among the sponges
c. any over-arching factors that are applicable to all of the sponges
d. the relationships among the sponges.

In particular, the scheme and format must:
easily incorporate a new and different sponge sample.

During your presentation to the whole group you will be presented with a new sponge and asked to describe it by fitting it into the scheme and format that you are presenting.

Some rules:

- Use a large piece of presentation paper to construct your format and scheme.
- You may ONLY use black markers – no color coding is permitted. Neither may you use typographical coding.

DEFINING THE CONCEPT OF

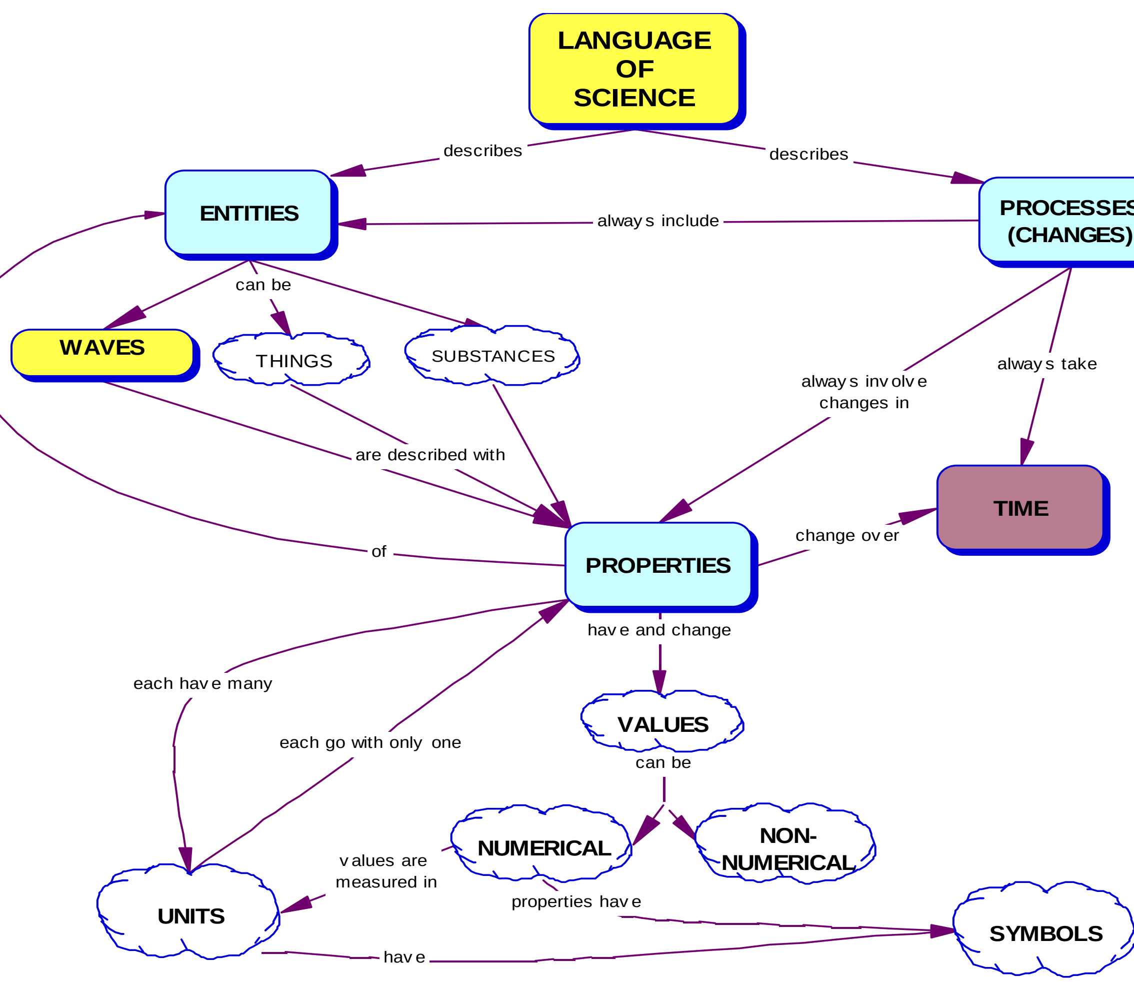
THE LANGUAGE OF SCIENCE

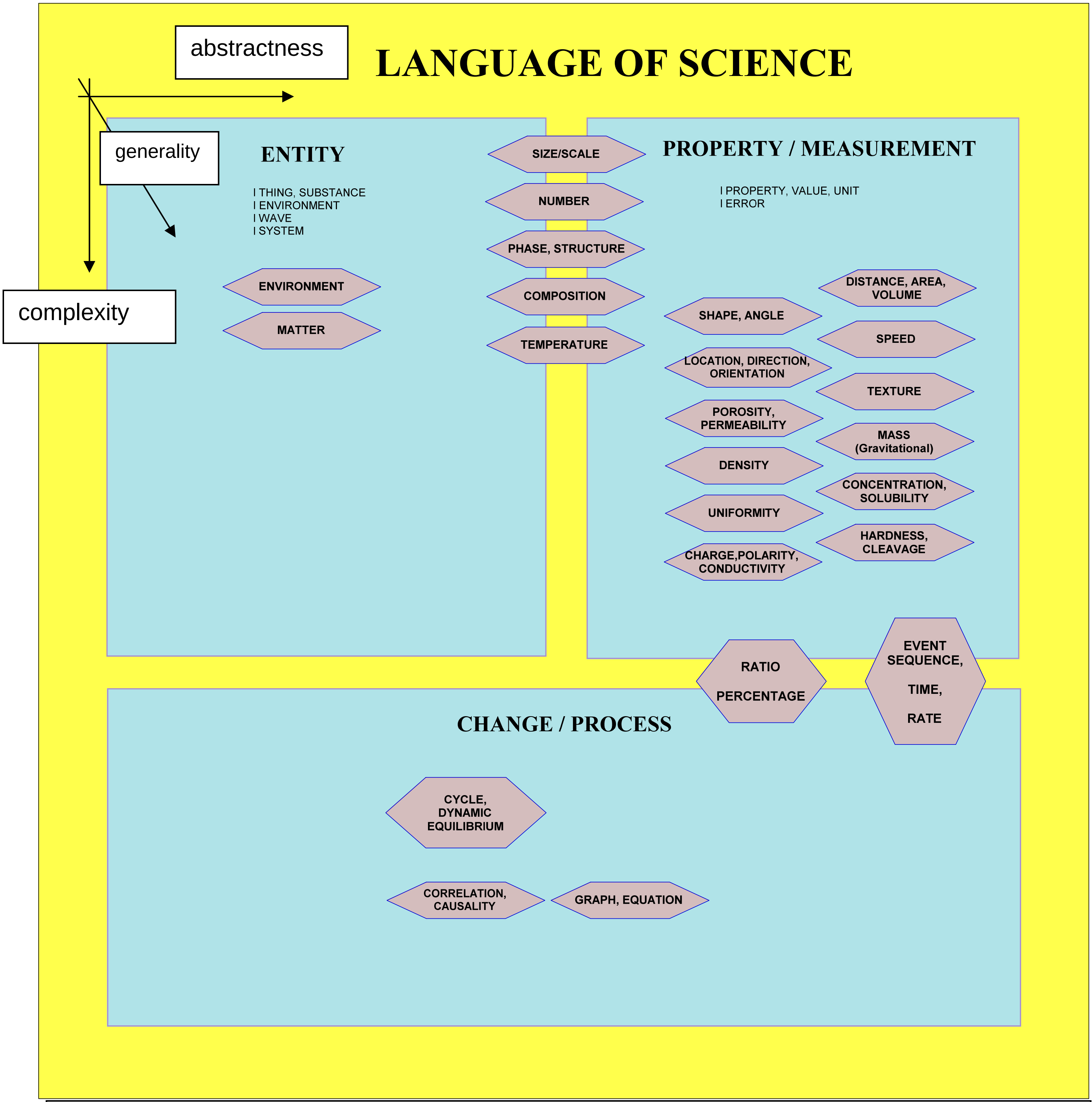
GENERALIZATIONS:

1. The natural world is imagined as delineated into things and composed of substances and waves which we think of as discrete (separate) entities and that we identify with names: What is it?

2. The entities that make up the natural world are described in terms of their properties.
   A. Properties have values, numerical or words, that are on a scale.
   B. Numerical values are measured in one of several possible units; each unit goes with only one property.
   C. Numerical properties and units (and sometimes entities and values) are represented with symbols.

3. The changes that occur throughout the natural world are described in terms of property changes: What happened?
   A. Processes always involve entities (things, substances, and/or waves).
   B. During any process at least one property of an entity changes values.
   C. During any process the change in value always takes time.





The Language of Science is the basic concept that underlies all eleven others. It is truly the language used to describe all observations and processes in scientific terms. Five of the properties (size/scale → temperature) bridge between Entity and Property because they are the five properties most often used to distinguish one thing or substance from another. Similarly, there are concepts that bridge between Property and Change/Process because they are both properties as well as tools for analyzing processes.

SOME PROPERTIES OF THINGS, SUBSTANCES, WAVES

number	N	weight	W
Price	P	density	D or ρ (Greek letter rho)
temperature	T°	texture	no symbol
distance	d	Porosity	Φ (Greek letter phi)
distance: length	L	energy	E
distance: width	W	kinetic energy	E_k
distance: diameter	D	thermal energy	E_{th}
distance: radius	R or r	**Properties of Waves:**	
distance: circumference	C	wavelength	λ (Greek letter lambda)
area	A	frequency	f
volume, capacity	V	Amplitude	A
speed (velocity)	v	**Electrical Properties:**	
acceleration	a	voltage (potential)	V
Momentum	p	Electrical current	I
mass	M or m	Electrical resistance	R

SOME PROPERTIES OF EVENTS, PROCESSES

Time	t or T	Direction	⟶ (arrow)
number, total energy released/absorbed		probability	p or P

SOME PROPERTIES OF INTERACTIONS

force	F	pressure	P
gravity	g	strength	S

TEXT NOTES: WHAT IS THE LANGUAGE OF SCIENCE?

Singers often sing songs in a foreign language, with near perfect pronunciation, and yet have no idea of what they are saying. In the same way, many people, and students, recite lots of scientific facts with no idea about what they mean. The LANGUAGE OF SCIENCE is the basic concept that underlies all of science, including all the physical, life and social sciences. This is the concept that is the key to understanding science rather than just memorizing scientific facts. It is the concept that helps you understand what the words mean. The LANGUAGE OF SCIENCE is the key to description and observation of the natural world.

There are three major ideas contained in THE LANGUAGE OF SCIENCE. They are:

1) ENTITY, which can be THINGS, SUBSTANCES, or WAVES.
2) PROPERTY, including the VALUES of properties.
3) PROCESS, or events and changes.

ENTITIES: THINGS, SUBSTANCES, or WAVES:

Science begins by looking at the entire natural world as a collection of THINGS or SUBSTANCES or WAVES, like sound, radiation, or vibrations. Collectively these are referred to as ENTITIES. So the thinking behind science begins by dividing up everything around us into entities. There are things like clouds, continents, planets, solar systems, sand grains, books, bacteria, atoms, people, leaves, and many, many, many more. There are an infinite number of things in the universe. You identify things by drawing an imaginary line around them and giving them a name. Drawing a line around some*thing* automatically gives it a size, so all things have a size.

Substances are like water, rock, air, wood, plastic, metal and cloth. Substances have names like things do. However, substances are different because you can't draw an imaginary line around them. Substances could be any size, in any amount. When you say "water," you could mean a drop or an ocean of water. You can take a breath of air, or have a whole atmosphere of it. You usually think of substances when you think of what something is made out of. So nails are made out of iron (a substance), and mountains are made of rock. So the idea of a substance is strongly connected to the property of composition, just as the idea of thing is strongly linked to the property of size.

Waves are different from both things and substances. While both things and substances are made up of matter, waves are not. The Language of Science concept is a way of thinking, and in our minds we think of waves such as light and ocean surf as entities. Understanding is a way of thinking, and how you think about the natural world is as important as the facts about it.

PROPERTIES AND VALUES:

Science describes entities with PROPERTIES, such as size, shape, composition, phase, temperature, and density. Every property has VALUES. Shape has values like round and square. Phase has values like solid and liquid. Texture has values like rough and smooth. These are NON-NUMERICAL values because they are described with words. Very often values are NUMERICAL, meaning they are given as numbers to tell you exactly how much of the property the entity has. So the length of a finger could be 5.2 centimeters (cm), or the length of a road could be 23.6 miles (mi). Values for the temperature of air could be 75 degrees Fahrenheit or 21 degrees Celsius. The values for density are also numerical. So the density of water is 1 gram per cubic centimeter, and the density of rock is around 3 grams per cubic centimeter. The value of a property tells you how much of the property its entity has (less-much, low-high, weak-strong).

Numerical values always have a UNIT attached to them, such as centimeters or miles for a length, degrees Fahrenheit or degrees Celsius for temperature, or grams-per-cubic-centimeter for density. The unit tells you how the numerical value was measured.

We identify and compare different entities with properties. Ice cubes and steam have different values for phase and temperature, even though they have the same value for composition (i.e. they are made out of water). Different nails can have different compositions (iron, aluminum, and even copper), different lengths, different masses and even different shapes.

Some properties can be both numerical and non-numerical. Numerical values for temperature were given as examples, but you could also use non-numerical values such as hot, cold, or frigid.

PHYSICAL AND CHEMICAL PROPERTIES, AND OUR SENSES.

Properties such as size, number (how many are there?), temperature, distance, and mass are PHYSICAL properties. Almost all properties are physical properties. There is really only one chemical property: composition (what something is made out of). Composition is the chemical property because the composition of a thing or substance changes during any chemical reaction. While all properties are divided into the two categories, the division is anything but even. There is one property in the chemical category, while there is a huge, ever expanding list of properties in the physical category. Changes in composition are so important in our universe and for life that it deserves its own category, as weighty as all the others put together. The field of chemistry is devoted to studying composition and its changes.

Composition is a difficult property to describe. It is associated with the idea of substance because we often describe composition as a list of ingredients or components. You would say that air is made up mostly of nitrogen and oxygen, with a bit of carbon dioxide thrown in. Sometimes composition can be described numerically using percentages, so you could say that air is 79% nitrogen, 20% oxygen, and less than 1% carbon dioxide and other trace substances. Composition is often difficult to describe if the ingredients or components are not obvious. The exact, numerical composition of Coca-Cola is still a secret, even though many people have spent decades trying to figure it out. Most perfumes have secret ingredients.

The last major point about the property of composition is that we (as well as most other organisms) sense composition with our senses of color, smell, and taste. We are so used to these senses telling us composition that we often think of color, smell, and taste as properties, but they are not. They are senses. Whenever we detect a change in color, smell, or taste we can safely conclude that a change in composition has taken place, even if we can't describe the exact change in the ingredients or components. What is incredible is that half of our senses (think of color as half of sight) detect only the one property of composition. Again, this one property seems so important and deserves its own category as a chemical property.

PROCESSES:

A PROCESS is a change. It is a happening, an event, an occurrence, a phenomenon. A storm is a process. So is an earthquake, a heartbeat, a wink, a soccer game and erosion. Processes often have names ending in -ing, such as cooking, playing, sunbathing, sleeping, orbiting, exploding, breathing. All of these processes involve a change, and it is the values of the properties of entities that change. That is what change means.

All processes follow three rules:

1. All changes, processes and events involve things, substances or waves.

2. During any change, properties of the involved things/substances/waves change values.

3. The changes in property values that occur during any process always take time.

For example, blowing a gum bubble is a process. This process involves the gum as well as your mouth and the air you blow into the gum. While blowing the bubble your mouth changes shape, the diameter of the bubble increases while its thickness goes down (eventually it gets so thin that it breaks). The volume of air inside the bubble increases too. Finally, the whole process take maybe 3 to 5 seconds. You could describe the process of bursting the bubble in the same way, but this time the sound wave would also be an entity that you would describe. Now think of an earthquake. An earthquake can last for several minutes. Continents are the things involved, and their speeds change during the earthquake. The speeds of the continents are the same before and after the earthquake, but DURING the earthquake, their speeds change.

THE THREE PARTS OF SPEECH
OF THE
LANGUAGE OF SCIENCE

TASK: In each of the blank boxes, fill in the equivalent or associated ideas as referenced in the subject areas.

SCIENCE	LANGUAGE ARTS	MATH
THING, SUBSTANCE, WAVE (ENTITY)		
	ADJECTIVE	
		PATTERN, EQUATION

THE THREE PARTS OF SPEECH
OF THE
LANGUAGE OF SCIENCE

SCIENCE	LANGUAGE ARTS	MATH
THING, SUBSTANCE, WAVE (ENTITY)	**NOUN,** **SUBJECT**	SUB-TEXT: **often ignored or excluded**
PROPERTY, CHARACTERISTIC, TRAIT, FEATURE, OBSERVATION	**ADJECTIVE**	VARIABLE, PARAMETER, QUANTITY, the UNKNOWN
PROCESS, EVENT, CHANGE, RELATIONSHIP	**VERB**	PATTERN, EQUATION

REVIEW OF THE MASTER CONCEPTUAL STRUCTURE FOR SCIENCE

TASK:

Turn to section 4 of your PD binder. Page in to the first and second pages of the Venn diagrams on which the twelve basic concepts are diagrammed, followed by a zoomed in look at Language of Science.

GROUPS A and B (working separately): Reference the first page of the Venn diagrams on which the twelve basic concepts are diagrammed. In the time allotted, come to consensus on the following question and record your responses and ideas on a white board to share out with the whole group.

> How/Why are the twelve basic concepts organized and shaped the way they are? Would you have any recommendations for how to improve the design of the page to better communicate its intentions?

GROUPS C and D (working separately): Referencing the second page of the Venn diagrams illustrating the Language of Science, come to consensus on the following question and record your responses and ideas on a white board to share out with the whole group.

> How/Why are the sub- and sub-sub-concepts organized and configured the way they are? Would you have any recommendations for how to improve the design of the page to better communicate its intentions?

REPORTING OUT: All participants are to take notes on the pertinent pages from the discussion led by each group's reporting.

ALL GROUPS: Reference the worksheet THE THREE PARTS OF SPEECH OF THE LANGUAGE OF SCIENCE. In groups, come to consensus on the appropriate terms for each of the blank boxes. Record your responses on a white board. Share your group's responses and modify your as needed. Turn to Section 5 of your PD binder and insert the completed page THE THREE PARTS OF SPEECH OF THE LANGUAGE OF SCIENCE. Add any additional terms that were generated by the group task and discussions.

ALL GROUPS: Discuss and record on a white board a consensus response to the following question:

> Why can students literally be able to read, yet still have a difficult time comprehending a science-related newspaper article or a science text book?

ANSWER KEY:

CAN YOU SUMMARIZE DESCRIPTIONS OF EIGHTEEN PROPERTIES?

For each of the following thirteen properties,

A. Give a short description of how or what it describes about a thing. Indicate at the end of each description whether the property is NUMERICAL or NON-NUMERICAL.
B. Give at least three examples of values. If the values are numerical, you must include the units in which the numbers were measured.
C. Write two sentences using the property or its values/units to describe things, substances or waves (entities.)

1) **SIZE: (Scale)** How big or small it is compared to something else, usually the human body. (Non-numerical)

B) Values: i) big ii) small iii)medium, enormous, huge, tiny, giant

C) i) Elephants are much bigger than bugs

ii) The stone was about fist-sized.

2) **NUMBER, N:** A) A count of similar entities. How many? (Numerical but without units – this property is an exception to the rule that numerical values have units. Also non-numerical)

B) Values: i) 38; 2,459; etc ii) million, dozen (words that mean numbers) iii) few, several, many iv) uni-, di-, tri-, quad-, penta-, … poly.

C) i) There are 13 players on a soccer team, including the substitutes.

CAUTION: You don't count units! You count <u>entities</u>. You <u>measure</u> a numerical property in units. Therefore values for Number cannot be negative, whereas a measurement in units can be.

3) **COMPOSITION**: A) What it is made out of, sensed by color, smell, and taste. (non-numerical or numerical when using percentages.)

B) Values: i) plastic, glass, metal, iron ii) propylene glycol iii) 79% Nitrogen, 20% Oxygen

C) i) Cars are mostly made of steel while bicycles are mostly made of aluminum.

ii) The oceans are made up of 96% water and about 4% salt.

4) **PHASE**:(State of matter) How easily it changes shape and volume, sensed through touch by pressing (non-numerical).

B) Values: i) solid, liquid, gas ii) hard, soft, squishy iii) firm, gooey, runny, "thick," molten (also implies temp)

C) i) I put liquid gas in my car to keep in running. (The word "gas" is short for gasoline.)

ii) When bread goes stale it gets much harder, often as hard as a rock.

5) **TEMPERATURE, T^o:** How much heat it has (either numerical or non-numerical)

B) Values: i) 32 °F ii) 56 °C iii) warm, frigid, scalding, chilly, molten (also means phase)
C) i) A kitchen oven can heat food up to over 400 °F.
ii) A greenhouse can keep plants very warm even when the outside air is freezing cold.

The Dimensional Properties

6) **DISTANCE, d, D: (length, width, radius, etc)** The measure of a LINE from one end to the other,
such as a string going between two points on an entity. (Numerical) One Dimension (1-D)

B) Values: i) 547 mi ii) 56 cm iii) 3.5 mm

7) **AREA, A:** The measure of its SURFACE, such as you would paint or wrap (numerical). Two dimensional, 2-D.

B) Values: i) 547 mi^2 ii) 56 cm^2 iii) 3.5 mm^2

8) **VOLUME, V: (Capacity)** The measure of the SPACE it takes up, or that you could fill with a substance. (Numerical). Three dimensional, 3-D.

B) Values: i) 547 mi^3 ii) 56 cm^3 iii) 3.5 mm^3

THE VALUES AND BASE UNITS CORRESPOND, WHILE THE EXPONENTS FOLLOWS THE DIMENSIONS.

9) **SHAPE:** Its outside form, outline, or silhouette (non-numerical)
B) Values: i) Rectangular, circular, etc. ii) Rounded, angular, jagged, flat iii) branching; Leaf-shaped, Pear-shaped
C) i) Traffic STOP signs are octagons while CAUTION signs are triangles.

10) **CONFIGURATION:** The arrangement or relative positions of the internal parts of an entity. (non-numerical)
B) Values: i) (a)symmetrical, (un)balanced ii) centered, radial, concentric, bilateral, lattice iii) lopsided
C) The configuration of the pieces in a chess game dictates who is winning and who is losing.

11) **TEXTURE:** How closely spaced and how high the bumps are on a surface, sensed through touch by rubbing back and forth. (Non-numerical)
(NOTE: Texture is the same as luster, which uses light reflection to measure texture).
B) Values: i) rough ii) smooth iii) bumpy, slippery, silky, fuzzy, slick, bald, wrinkled
C) i) Polishing furniture smoothes out the bumps by adding polish in the scratches to make a very smooth and shiny surface.
ii) The most important property of car tires is the texture of their tread, which becomes smoother and smoother, and eventually bald, with use.

12) **POROSITY, Φ:** How hole-y it is. The percentage of open space (volume) in it in between the material particles. (Numerical percentages, so without units)

B) Values: i) 20% (e.g. wood) ii) 81.60% (e.g. sponge) iii) 5.3% (e.g. skin)

C) i)There is no such thing as 0% porosity; even iron is 0.001% porous, otherwise it would never rust.

13) **MASS, M, m:** How much material, substance or matter is in it; how much stuff. (Numerical)

B) Values: i) 54 lbs ii) 78.65 g iii) 65 kg

> The difference between weight and mass is underplayed if mentioned at all. Here on the surface of Earth, they can be considered for most purposes to be close enough to be synonyms until motion and force concepts are the focus.

14) **DENSITY, ρ, D:** How packed together (compact) or spread apart its material particles are. Can describe linear, surface and mass densities. Mass density: How much mass is packed into a space; the comparison (ratio) of its mass to its volume. (Numerical)

B) Values: i) 23 lb/in^3 ii) 45.6 g/cm^3 iii) 58 kg/m^3

> g/cm^3 is the most common standard unit. Density of cold water is 1 g/cm^3 , so it's easy to compare other densities to water's, especially for float-sink ideas.

C)Cotton candy is much less dense than rock candy.

15) **LOCATION:** Where an entity is found within its environment. (Numerical or non-numerical).

B) Values: i) latitude and longitude ii) on top, behind, inside, the edge, the center, in the middle iii) location names (New York, Australia, the Northeast)

16) **DIRECTION:** Where an entity is moving to, might move to, or is pointing. (Numerical or non-numerical). **ORIENTATION** also describes the direction an entity is pointing or facing.

B) Values: i) points of the compass: N, NW, WNW ii) forward/reverse, sideways iii) bearings (numerical)

17) **PROXIMITY**: How close or far apart two entities are. This is a non-numerical version of the distance between two entities.

B) Values: i) close, fairly close, far apart, adjacent, touching

18) **ALIGNMENT:** How similar the directions or orientations of two entities are. (Non-numerical or numerical)

B) Values: i) parallel, perpendicular, skewed, crooked ii) measured numerically using the angle between the two directions.

NAME: PERIOD: DATE:

QUIZ: WHERE ARE PROPERTIES IN SENTENCES

For each of the following statements, indicate which entity and which property it is describing. Then give the value(s) and unit(s) specified for the property. The values and units must be paired correctly if there are more than one.

1. The Earth's continents are made up of almost all quartz mixed with metals such as calcium, sodium, and aluminum that give the quartz different colors.

ENTITY	PROPERTY	VALUE	UNITS

2. The Earth's oceans cover about 71% of the planet's surface, for a grand total of about 140 million square miles. (362 x 10^6 km^2.)

ENTITY	PROPERTY	VALUE(S)	UNIT(S)

3. Sound travels in water at 1500 m/s, about four times faster than in air.

ENTITY	PROPERTY	VALUE(S)	UNIT(S)

4. 1. The average depth of Earth's oceans is 12, 200 ft (3,270 m), or about 2 1/3 miles.

ENTITY	PROPERTY	VALUE(S)	UNIT(S)

5. The Antarctic ice cap has an average depth of 2,100 m (7000 ft).

ENTITY	PROPERTY	VALUE(S)	UNIT(S)

6. The Arctic ice cap, which is floating on the Arctic ocean, had an average thickness of 3.1 meters 50 years ago, but by the end of the 1990's it had decreased by almost half to 1.8 meters.

ENTITY	PROPERTY	VALUE(S)	UNIT(S)

NAME: ______________________________ DATE: ______ PERIOD: _____

PRACTICE WITH VALUE CHANGES DURING A PROCESS

FILL IN THE BLANKS WITH REASONABLE VALUES, INCLUDING UNITS WHEN NECESSARY. ONLY USE A SPECIFIC UNIT ONCE FOR EACH PROPERTY ON THE ENTIRE WORKSHEET.

1) PROCESS: Folding paper
THING/SUBSTANCE/WAVE: sheet of paper
PROPERTY: surface area

BEGINNING VALUE:________________ ENDING VALUE:__________________________

2) PROCESS: Making a snowball
THING/SUBSTANCE/WAVE: snowball
PROPERTY: density
BEGINNING VALUE: _______________ ENDING VALUE:___________________________

3) PROCESS: Writing your name
THING/SUBSTANCE/WAVE: line of ink applied to paper
PROPERTY: length
BEGINNING VALUE:_________________ ENDING VALUE: _______________________

4) PROCESS: Drinking a soda
THING/SUBSTANCE/WAVE: soda in the can
PROPERTY: volume
BEGINNING VALUE:_________________ ENDING VALUE: _______________________

5) PROCESS: Drilling a deep, deep well into Earth's crust
THING/SUBSTANCE/WAVE: Rock through which drill is cutting
PROPERTY: Temperature
BEGINNING VALUE:_________________ ENDING VALUE: _______________________

6) PROCESS: Steamrolling a newly laid road
THING/SUBSTANCE/WAVE: asphalt
PROPERTY: porosity
BEGINNING VALUE:_________________ ENDING VALUE: _______________________

7) PROCESS: Grinding coffee beans into coffee
THING/SUBSTANCE/WAVE: coffee grains
PROPERTY: surface area
BEGINNING VALUE:_________________ ENDING VALUE: _______________________

8) PROCESS: A growing tree
THING/SUBSTANCE/WAVE: tree trunk
PROPERTY: diameter PROPERTY: mass
BEGINNING VALUE:_________________ BEGINNING VALUE: _____________________
ENDING VALUE: ___________________ ENDING VALUE: _______________________

9) PROCESS: Typing a letter
THING/SUBSTANCE/WAVE: finger tip
PROPERTY: number of key strokes PROPERTY: height above key
BEGINNING VALUE:_________________ BEGINNING VALUE: _____________________
ENDING VALUE: ___________________ ENDING VALUE: _______________________

10) PROCESS: Whistling a tune
THING/SUBSTANCE/WAVE: sound
PROPERTY: wavelength PROPERTY: amplitude
BEGINNING VALUE:_________________ BEGINNING VALUE: _____________________
ENDING VALUE: ___________________ ENDING VALUE: _______________________

11) PROCESS: car jamming on brakes and skidding to stop
THING/SUBSTANCE/WAVE: tire
PROPERTY: speed of revolution PROPERTY: temperature

BEGINNING VALUE:________________ BEGINNING VALUE: ___________________
ENDING VALUE: __________________ ENDING VALUE: _____________________

12) PROCESS: baking a cake
THING/SUBSTANCE/WAVE: cake mixture
PROPERTY: density PROPERTY: temperature
BEGINNING VALUE:________________ BEGINNING VALUE: ___________________
ENDING VALUE: __________________ ENDING VALUE: _____________________

13) PROCESS: grating carrots for a salad
THING/SUBSTANCE/WAVE: carrot
PROPERTY: total surface area PROPERTY: porosity
BEGINNING VALUE:________________ BEGINNING VALUE: ___________________
ENDING VALUE: __________________ ENDING VALUE: _____________________

14) PROCESS: shooting an arrow
THING/SUB/WAVE: arrow
PROP:dist to target PROP: speed PROP: shape
BEG VAL:_________________ BEG VAL: _______________ BEG VAL:__________
END VAL:_________________ END VAL: _______________ END VAL:__________

15) PROCESS: dropping bombs from an airplane
THING/SUB/WAVE: airplane THING/SUB/WAVE: bombs being dropped
PROP: mass PROP: speed PROP: altitude
BEG VAL:_________________ BEG VAL: _______________ BEG VAL:__________
END VAL:_________________ END VAL: _______________ END VAL:__________

15) PROCESS: mowing the lawn with riding mower
THING/SUB/WAVE: cut blades of grass THING/SUB/WAVE: cut lawn
PROP: number PROP: volume PROP: area PROP: texture
BEG VAL:__________|| ___________ BEG VAL:__________|| ______________
END VAL:__________|| ___________ END VAL:__________|| ______________

17) PROCESS: making popcorn in a microwave oven
THING/SUB/WAVE: bag THING/SUB/WAVE: popcorn
PROP: volume PROP: temperature PROP: color PROP: density
BEG VAL:__________|| ___________ BEG VAL:__________|| ______________
END VAL:__________|| ___________ END VAL:__________|| ______________

18) PROCESS: running a marathon
THING/SUB/WAVE: body THING/SUB/WAVE: foot
PROP: temperature PROP: mass PROP: speed PROP:d above grnd
BEG VAL:__________|| ___________ BEG VAL:__________|| ______________
END VAL:__________|| ___________ END VAL:__________|| ______________

19) PROCESS: hitting tennis ball
THING/SUB/WAVE: racquet THING/SUB/WAVE: tennis ball
PROP: d above grnd PROP: speed PROP: direction PROP: shape
BEG VAL:__________|| ___________ BEG VAL:__________|| ______________
END VAL:__________|| ___________ END VAL:__________|| ______________

NAME: ______________________ PERIOD: ________ DATE: __________

WHAT CAN ALKA-SELTZER *REALLY* DO ??

Sure, a tablet of Alka-Seltzer can do something for a stomach ache. But what else can it do? Let's find out if we can make a rocket with it. As fun as this will be, the real **Purpose** of this activity is to have you observe and analyze what happens using the three principles common to all processes:

1) PROCESSES ALWAYS INVOLVE ENTITIES (Things, Substances, or Waves).
2) DURING ANY PROCESS, THE VALUES OF AT LEAST ONE PROPERTY CHANGE.
3) THE CHANGE IN A PROPERTY'S VALUES ALWAYS TAKES TIME.

You will record your analysis using the common template that will be used to analyze any process.

PROCEDURE:

1. Put on safety goggles. THIS IS ABSOLUTELY NECESSARY. THIS ACTIVITY CAN BE DANGEROUS.
2. Break the Alka-Seltzer tablet into four approximately equal pieces.
3. Fill the film canister about half-full of tap water. Carefully mark on the side of the canister the exact water level.
4. Drop one piece of Alka-Seltzer into the water and begin timing (in seconds) immediately and continue until the observed process ceases. Observe the changes in composition and other properties that occur.
5. Empty the film canister and re-fill it to the same depth in the canister as before.
6. Drop another quarter-piece of Alka-Seltzer into the canister and immediately replace the top. Begin timing as soon as the canister top is in place. BE SURE TO STAND BACK FROM THE CANISTER AS YOU WAIT FOR WHAT WILL HAPPEN.
7. a. Observe how high the top goes as accurately as possible. Measure the height.
   b. Continue timing until the process inside the canister ceases (as you did in step 4)
8. Repeat Steps 5 through 7 with the third piece of Alka-Seltzer to record your observations and measurements more accurately.
9. Repeat Steps 5 through 7 with the last piece of Alka-Seltzer as your final attempt to gather complete and accurate data.
10. Complete the chart on the back of this paper as a record of your observations and measurements.

NAME: ____________________

PROCESS NAME: ALKA-SELTZER ROCKET **SHORT DESCRIPTION OF PROCESS:** Carbon dioxide (CO_2) produced by reaction of Alka-Seltzer and water generates a pressure in a film canister which then causes the top to explode off.

SUB-PROCESS (in sequence)	ENTITY (Thing, Substance, wave)	PROPERTY	DESCRIPTION OF VALUE CHANGES Description of CAUSES: How, Why?	TIME or RATE
Alka-Seltzer fizzing in water in open container	Alka-Seltzer tablet	composition	Starts as sodium bicarbonate and citric acid and turns into carbon dioxide and water during the reaction. This water is in addition to the water that it reacts with. Chemical reaction occurs between the sodium bicarbonate and water.	
		phase		
	Bubbles composition: ________	location		
		volume		
	water	volume		
PART TWO: top quickly put back on canister after putting tablet in water				
Alka-Seltzer fizzing in water before top explodes off	Alka-Seltzer tablet	phase		
	Carbon dioxide	pressure in closed canister		
		volume		
Top exploding off of canister	Carbon dioxide	pressure in closed canister		
		volume (until no more is being produced)		
	canister top	height above canister		
	water			

VI

CURRICULUM PLANNING

and

DOCUMENTATION

WHY FOCUS ON CURRICULUM?

PROBLEM:

Over the past fifty years of education, enormous improvements, both in practice and theory have been made in education. Yet there is little corresponding improvement in student learning. Why?

The National Assessment of Educational Progress is our nation's only measure of educational progress over the past thirty years. It provides data on reading, science, and mathematics for 9-, 13-, and 17-year-old students. Generally, the trends in mathematics and science are characterized by declines in the 1970's, followed by increases through the early 1990's, and mostly stable performance since then. Mathematics has shown the best improvement, with about a 10 point increase in scores over the decades. In science, scores have improved slightly for 9-year-olds, but have actually declined for the older students. Although scores in reading improved during the 1970's for 9- and 13-year-olds, no further improvements have occurred since 1980. For the oldest students, reading scores today are not significantly different than they were in 1971. (Taken from "The Release of the NAEP 1999 Trends In Academic Performance," National Center for Educational Statistics, August 24, 2000.)

THESIS:

The improvements in instruction and assessment are being stymied by a lack of progress in curriculum.

The excellent improvements and innovations in education have been almost entirely in instruction or in assessment. Very little research, development or innovation has occurred with curriculum, where curriculum is understood to mean the description, organization and articulation of learning outcomes. The improvements in instruction and assessment have been necessary, but not sufficient.

HYPOTHESIS:

Fundamental improvements in curriculum design would bring direct and significant benefits to student learning. Furthermore, such curriculum improvements would also catalyze many of the potential benefits to student learning of exemplary instructional and assessment strategies.

CURRICULUM

PLANNING
ALIGNMENT
ARTICULATION
COORDINATION
DOCUMENTATION

⟶

FOCUSED ON
STUDENT LEARNING

⟶

CRAFTED WITH
COGNITIVE ENGINEERING

SOME BEGINNING ASSUMPTIONS ABOUT CURRICULUM FROM THE TEACHER'S PERSPECTIVE

a) Curriculum should build on what we have already done and the units that we have already developed.

b) The curriculum should also allow for teachers to practice their individual strengths as well as allow them to teach creatively.

c) The curriculum should be specific so that a grade-to-grade continuum is clear and workable.

d) The curriculum should be a simple document. It should be easy to refer to, easy to communicate to students and parents, and easy for new teachers to understand and follow.

e) The curriculum should focus on both content knowledge and problem solving skills as is required by the state frameworks and as will be tested by the external exams, but within a higher goal of teaching to students' potentials.
   1) Don't blame the test !!
   2) Authentic learning: students should do well on ANY test.

A COURSE CURRICULUM THAT IS EFFECTIVE AT IMPROVING STUDENT LEARNING SHOULD…

… above all else, be focused on student learning outcomes, and …

… FROM THE TEACHING PERSPECTIVE ,

a. be addressed to the teacher (i.e. teachers are the document's audience)
b. implement the school mission's vision, particularly as it addresses the intellectual goals for student learning
c. specify unit learning outcomes, unit sequencing, and unit duration
d. specify learning outcomes so that a course-to-course continuum is clear, coherent, and cumulative
e. be specific so that assessment of the specified learning goals is unambiguous and focused
f. be a simple document. It should be easy to refer to and easy for new teachers to understand what their students are to learn
g. allow teachers to practice their individual strengths, teach creatively, and grow professionally in content mastery
h. specify the common learning outcomes that colleagues are all and each responsible for
i . be a living document, in that it easily encapsulates and incorporates ideas for change and provides a framework for objective and rapid decision-making on curriculum changes

… FROM THE LEARNING PERSPECTIVE ,

a. specify the important information, key concepts, and essential skills that students need to know, understand and do
b. build on students' prior knowledge and challenge each student's intellectual limits
c. address how mandated learning standards are to be learned
d. reflect and incorporate what is known about the structure of intellectual knowledge, problem solving, and critical thinking

… FROM THE ADMINISTRATIVE PERSPECTIVE ,

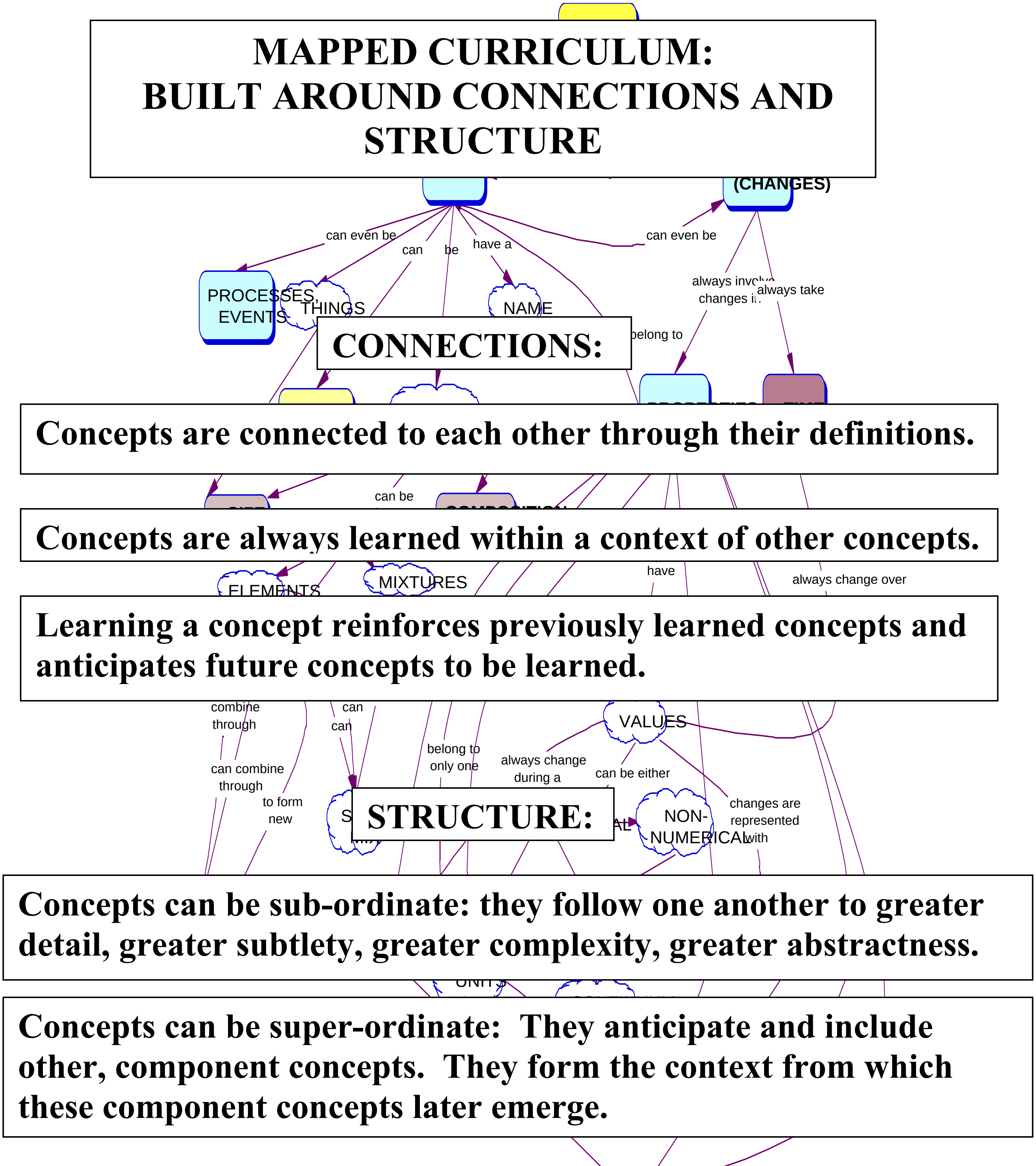
a. be easy to communicate to parents and community
b. evolve easily, efficiently and regularly as experience and circumstances change
c. be robust enough to only require minor changes to accommodate changes in mandated standards
d. Provide clear direction for instructional practice, assessment design and feedback pathways among the three dimensions of curriculum, instruction and assessment.
e. Clearly link course curricula with unit designs, which are linked to lesson plans
f. Be easily supervised and incorporated into teachers' yearly professional goals

TWO OPTIONS FOR CURRICULUM ALIGNMENT

STANDARDS

SPLINTER and SPIRAL	CHUNK and CONNECT
STANDARD → Introduce, Reinforce, Proficient, Master	STANDARD, STANDARD, STANDARD, STANDARD → Concept & Skill
Leads to coverage of many, many standards with little carry-over from year-to-year.	Leads to un-coverage of a few concepts and skills through the links among many standards.

MAPPED CURRICULUM: BUILT AROUND CONNECTIONS AND STRUCTURE



CONNECTIONS:

Concepts are connected to each other through their definitions.

Concepts are always learned within a context of other concepts.

Learning a concept reinforces previously learned concepts and anticipates future concepts to be learned.

STRUCTURE:

Concepts can be sub-ordinate: they follow one another to greater detail, greater subtlety, greater complexity, greater abstractness.

Concepts can be super-ordinate: They anticipate and include other, component concepts. They form the context from which these component concepts later emerge.

Concepts can be co-ordinate: At the same scale within the webbed structure, these concepts often emerge together and reinforce each other as much through difference as similarity.

THE SPIRAL CURRICULUM

Introduce	→	Reinforce	→	Proficient	→	Master

Typical curriculum structure:

1. Mandated standards are each split into smaller steps that correspond with the levels of the spiral.
2. Steps are allocated to different grades or courses, with each taking responsibility for at most two consecutive steps for a particular standard.

	PATTERN OF YEAR-TO-YEAR RETENTION	TYPICAL PATTERN TO REACH PROFICIENCY	DEPTH vs. BREADTH
CONVENTIONAL SPIRAL CONTENT CURRICULUM N.B. Facts are by their nature distinct from each other. Connections are thru surface features.	Depends upon student memory of isolated information. Considerable review required each year. Vague distinctions between levels: What is the difference in learning between introduction and reinforcement?	Depends upon year-to-year, fact-based retention, which is poor for most students. For students with good study skills, 3+ years to reach proficiency level where recall of information is spontaneous, adequate, and accurate.	Learning is generally shallow because of required review of past information. Because of student reluctance to repeat past learning, new information is preferred and learning is spread over many topics.
CONVENTIONAL SPIRAL SKILL CURRICULUM N.B. Skill proficiency requires repetition over extended time.	Skills must be initially repeated often for long-term retention. Once a skill is acquired to proficiency, it is generally retained for long periods of time. Fewer required skills (compared to content info.) leads to more practice for each.	Initial repetition over days and weeks, with subsequent use of 2+ years to reach mastery. A first learning plateau of an operational and useful ability is often reached fairly quickly with concentrated teaching and practice. Proficiency then improves steadily with time and practice to mastery.	Skills are generally coherent and their necessary components well prescribed – thus skills are rarely considered to be cognitively "deep." Some skills are generic to many areas, but most are fairly well focused on particular uses.
MAPPED CURRICULUM ORGANIZED BY CONCEPT N.B. Concepts are by their nature inter-related. They are defined by their connections to other concepts.	Both long-term retention and rapid recall are high. Concepts are the organizational linkages of the mind and are thus retained once learned. Concepts cannot be learned without reinforcing previously learned concepts and anticipating concepts to be learned in the future. A spiral or reinforcement and introduction is "built-in" to any conceptual structure.	Concepts must be learned as a coherent whole with necessary and sufficient components to be minimally useful for transfer. Considerable time (weeks) is required to learn a concept to an initial level of transfer, with practice of transfer-ability dominating the final stages of learning.	Concepts are introduced through their connections to other concepts that are the actual focus of instruction. Once a concept is the focus of instruction, it is learned deeply. Simple concepts become the pre-requisites for more complex concepts learned later. Breadth and Depth merge.

HOW MIGHT YOU ORGANIZE UNITS FOR THE FOLLOWING CONCEPTS AND TOPICS?

Suppose you were considering designing four units with a 3-D plan so that each unit had students combining transferable concepts with specific topical information. The following two boxes list the concepts and the topics that need to be covered in the four units.

CONCEPTS	TOPICS
Composition	The Cell
Energy Transformation	Plate Tectonics
Interdependence	Amusement Park
Cycle	Pollution

Using the below chart outline how you might structure the four units as combinations of concepts and topics.

UNIT NAME	CONCEPTS	TOPICS

MAJOR UNDERLYING PRINCIPLES UPON WHICH CRAFT IS BUILT

1.	All/Any Learning Outcomes	=	Transferable Concept	±	Topic Context	±	Skill	

2a.	Content (= concept + topic)	+	Skill	=	Lower Thinking Processes (Knowledge, Comprehension)
2b.	Transferable Concept	Skill +	Topic/ Context	=	Higher Thinking Processes (App., Anal., Syn., Eval.)

3a.	Development Patterns of Transferable Concepts As well as Topics/Contexts and Skills	General (Obvious)	→	Specific (Subtle)
3b.		Simple	→	Complex
3c.		Concrete (Objective)	→	Abstract (Subjective)

4.	One-Concept Many-Topics	←——————→	One-Topic Many-Concepts

TWO POSSIBLE APPROACHES TO
3-D CURRICULUM DESIGN
and
UNIT ORGANIZATION

I. ONE-CONCEPT, MANY-TOPICS:

(Units are organized around concepts)

		Topic	=	Higher thinking processes:
	+			application
		Topic		
Concept	+		=	analysis
		Topic		
	+			synthesis
		Topic	=	evaluation

How easily can a concept be taught without any topic?

In this approach, how easy is it for the concept to disappear?

How easily does this approach accommodate to differences in students' interests and backgrounds?

Other features of this approach:

II. ONE-TOPIC, MANY-CONCEPTS:

(Units are organized around topics)

		Concept	=	Higher thinking processes:
	+			application
		Concept		
Topic	+		=	analysis
		Concept		
	+			synthesis
		Concept	=	evaluation

How easy is it for the concepts to "disappear" into the topic, producing a homogenized content?

What would be the effect on learning if the concepts "disappeared" ? (meaning they were no longer distinguished from the topic)

How easily does this approach accommodate to differences in students' interests and backgrounds?

Other features of this approach:

TWO APPROACHES TO COURSE CURRICULUM DESIGN
focused on Higher-Order Thinking

<u>ONE TOPIC, MANY CONCEPTS</u>:

	+	Concept	=	Higher thinking processes:
	+	Concept	=	Application
Topic	+	Concept	=	Analysis
	+	Concept	=	Synthesis
	+	Concept	=	Evaluation

FEATURES:
a) Familiar
b) Corresponds with textbook organization
b) Fits library, internet archiving
c) Good definition of life-long learning
d) If concepts are ill-defined, then approach collapses to 2-D.

<u>ONE CONCEPT, MANY TOPICS</u>:

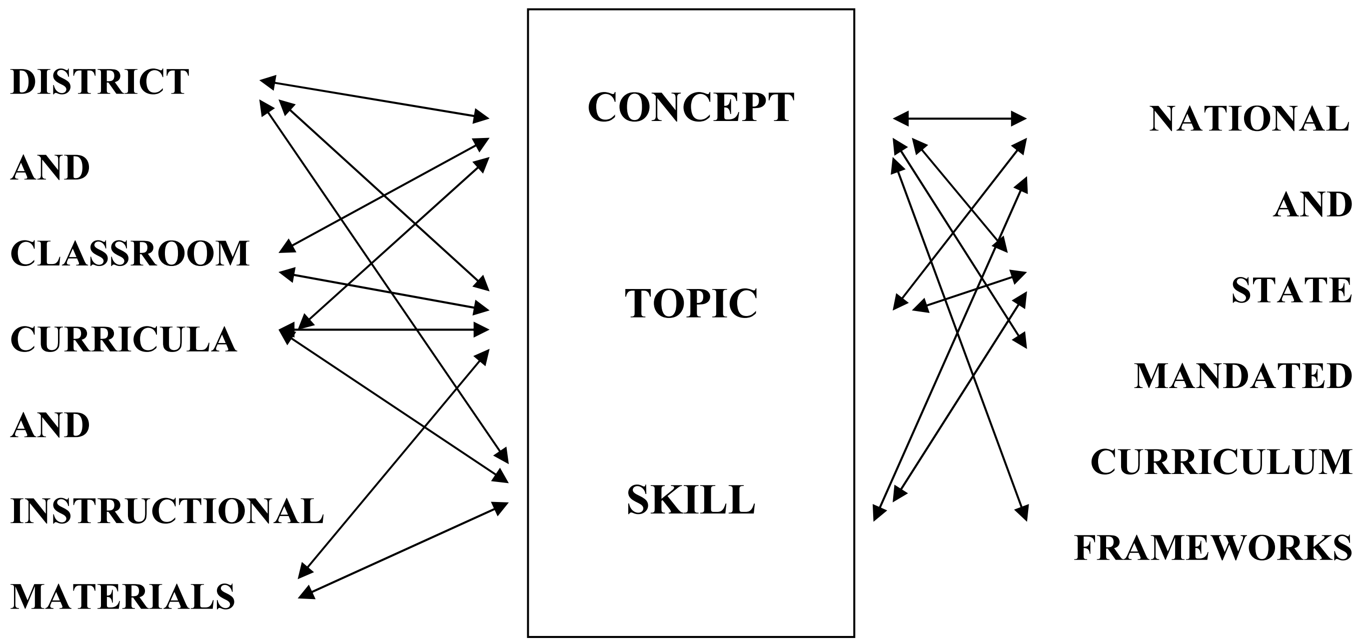
	+	Topic	=	Higher thinking processes:
	+	Topic	=	Application
Concept	+	Topic	=	Analysis
	+	Topic	=	Synthesis
	+	Topic	=	Evaluation

FEATURES:
a) Integrates topics
b) Can't collapse; concepts can't be learned without a context
c) Topic can adapt to student, teacher, school, community.
d) Structured knowledge leads to high AND long retention of contextual knowledge.
e) Highly efficient and rapid learning of topic information.

OFTEN IN PRACTICE:

One-topic + many-concepts ← **continuum** → One-concept + many topics

THE ADVANTAGE OF A CURRENCY OVER A BARTER SYSTEM



AN INTERMEDIATE CURRENCY ALLOWS EITHER SIDE TO CHANGE WITH A MINIMUM OF DISRUPTION TO THE OTHER

CURRICULUM DOCUMENT HIERARCHY

FIRST LEVEL: DISTRICT CURRICULUM.

1) A SUMMARY OF CONCEPT, SKILL, AND TOPIC/CONTEXT benchmarks for a span of grades, also indicating a distribution of responsibility for learning benchmarks for each grade level or course. Sequences of courses or learning outcomes are articulated across relevant grade spans and transition points.

2) A COLLECTION OF COURSE CURRICULA.

SECOND LEVEL: COURSE CURRICULUM .

1) A SUMMARY CURRICULUM MATCHING SKILLS WITH TOPICS AND CONCEPTS WITH TOPICS. (Language Arts will have multiple units for each course. Literature and Composition units will match texts (the equivalent of topic) with concepts and skills. Grammar units will only list skills.

2) A CURRICULUM PLAN THAT LISTS ALL THE FRAMEWORK STANDARDS MATCHED WITH THEIR RESPECTIVE SKILLS, CONCEPTS, TOPICS AND SAMPLE ASSESSMENTS.

3) THE SUMMARY CURRICULUM (see #1 above) FOR THE COURSE OF STUDY IN THE PRECEDING YEAR, AND THE SUMMARY CURRICULUM FOR THE COURSE IN THE SUCCEEDING YEAR.
(Where are your students coming from, and where are they going to?)

4) THE MASTER CONCEPT STRUCTURE AND SKILL SEQUENCE FOR THE SUBJECT AREA. (What is the larger context within which students are learning?)

THIRD LEVEL: UNIT CURRICULUM

Each course is divided into units. In most courses, each unit focuses on one or multiple concepts, or one or more skills. In Language Arts, literature units have a topic focus such as "Courage and Survival," "Coming of Age," "Folklore," etc.. There are also composition and grammar units in Language Arts that generally have no topic focus.

CURRICULUM UNIT LEARNING PLAN

1) Title
2) UNIT OVERVIEW: Definition and overview of the concept(s) or skill(s) to be addressed in the unit. Concept mapping of the concept(s) can clearly summarize the connections to prior and future learning. Also describes the general strategy for teaching the concept/skill(s) and how they will be combined with the topics.
3) BASIC SKILLS AND INFORMATION: Lists the basic skills and/or information to be introduced, mastered or reviewed in the unit.
4) RELEVANT FRAMEWORK STANDARDS. Lists the standards that are specifically addressed in the unit.
5) SAMPLE ACTIVITIES. Some suggestions on what types of learning experiences would be appropriate.
6) SAMPLE CULMINATING ASSESSMENT TASKS: Some suggestions for the end-of-unit assessment.
7) SUGGESTED RESOURCES . Reading lists or other resources (materials, videos, Field trips, etc.).

FOURTH LEVEL: LESSONS AND ACTIVITIES (INSTRUCTIONAL MATERIALS)

Teachers choose particular lessons and activities as they see best to ensure that students learn the curriculum.

THE PROCESS OF DESIGNING A CONCEPT-BASED CURRICULUM MAP: A BRIEF DESCRIPTION

This paper briefly describes the process a school or district might follow for designing, articulating, and aligning K-12 course curricula with standards using a concept-based model. Many issues (e.g. financing, professional development, community involvement) that form the context for the process and that would affect it in many ways are not addressed. For example, it is assumed that some kind of curriculum leadership team for the school or district has been formed and is managing the process. Although curriculum reform necessarily affects instructional practices as well as the assessment of student learning, this paper only briefly touches on these other two components of classroom practice. This said, it is important to note that concept-based curriculum reform is built on the excellent innovations of the past decades in instructional practice (e.g. cooperative learning, student-centered inquiry, differentiated instruction) and assessment design.

The first step in creating a concept-based curriculum map, particularly at the secondary level, is to lead a discussion within a leadership team on the ultimate goal of education for their students: are they educating for literacy for all, or are they identifying and preparing future career specialists? Although the first goal contains the second, the reverse is not true. Such a discussion hinges on what is meant by literacy. Basic facts, information, and skills are certainly a component, as detailed in many national and state curriculum frameworks, SAT II, Advanced Placement, and prior district syllabi. Alongside essential skills and facts, such documents also place a premium on the goals of higher order thinking, deep conceptual understanding, problem solving, critical thinking, learning to learn, etc. This second category of learning outcomes can be distilled to the goal of knowledge transfer. With a base of essential skills and facts, students should be able to transfer and apply knowledge to new questions, situations and contexts, motivating and orchestrating the process themselves. Concept-based curriculum was designed from its inception as a vehicle for accomplishing such learning with all students.

Concept-based curriculum reform focuses on knowledge transfer. In the process of knowledge transfer, what transfers, and what stays behind? Any meaningful learning experience combines generic, transferable knowledge with specific facts pertaining to the context. These generic, transferable concepts (e.g. ratio, form-and-function, conflict) can be intellectually carried to a seemingly unrelated context or topic where they are applied in creative problem solving and critical thinking. Transferable concepts that are useful for flexible problem solving and critical thinking are a sub-set of the many types of ideas referred to generally as concepts.

Concept-based curriculum theory rigorously distinguishes between transferable concepts and concepts-in-general. Continuing this line of reasoning, it then looks at the relationships among transferable concepts in order to map how new conceptual learning can be constructed from prior conceptual understandings. The concepts and their relationships are organized into a clear, concise structure that reflects three patterns of cognitive development: obvious to subtle (i.e. general to specific), simple to complex, and concrete to abstract. These conceptual structures (each major subject area has a unique structure) summarize and clarify a wide breadth of cognitive and educational research in a form useful to curriculum planners and teachers.

Referring to such a conceptual structure, a curriculum leadership team can quickly analyze any set of standards. Seemingly voluminous standards are inevitably distilled to a few transferable concepts and associated topic information and skills. Students deeply learn the concepts by applying them to a wide variety of different specific situations and contexts. Some applications, derived from the standards, will be required of all students, but many will be chosen by teachers and students to accommodate the many different backgrounds, interests, skill levels, and resources that characterize classrooms today.

The curriculum leadership team can then distribute the required concepts, contexts, and skills among the various grade levels and courses that were within the grade span covered by the original standards documents. The distribution depends primarily upon considerations of cognitive development and prior learning, since the concepts are organized accordingly. The leadership team can reasonably articulate grade-to-grade curricula since the conceptual structure maps the relationships that would exist among the curricula of even widely separated grade levels. The team also distributes and coordinates mandated contexts and topics among the grade levels. A multitude of concept-context combinations is possible, giving the leadership team the opportunity to create a plan that reflects their own history and priorities. In most states, mandated topics prescribe at most half of classroom time, leaving ample time for teachers and students to use the concepts to explore and investigate their own interests. With only about three to five concepts assigned to each course of study, time is available for developing deep understanding of each concept. Teachers and students have a clear, explicit curriculum model within which to practice transferring knowledge. The resulting long-term understandings form a robust, dynamic basis for their next year's learning.

Transferability is a major attribute of the concepts used within concept-based curriculum planning. A second major attribute is definability. To be educationally useful, transferable concepts must be defined for two reasons: so that teachers clearly understand what they are teaching towards, and so that student understanding can be assessed. Every concept can be defined with a small set of generalizations or propositional statements. These generalizations describe the essential understandings that together form the coherent, transferable concept. They describe the desired learning outcomes beyond mere vocabulary, and are the basis for constructing rubrics and assessments. Conventional and standardized testing are adequate for assessing a student's comprehension of facts, information and even skills. The generalizations provide the keys to developing valid and reliable assessments of a student's ability to transfer knowledge.

A curriculum leadership team can develop assessment items that ask students to combine the concepts and contexts assigned to a course of study, the generalizations providing the basis for a scaled evaluation of students' responses. Such an end-of-course assessment can greatly affect classroom practice because it focuses clearly on students' ability to transfer knowledge using the assigned concepts. Furthermore, the most practical and efficient method of teaching this high-level ability is to organize intended learning according to the duality of concept and context/topic, as would be delineated in the curriculum documents.

A leadership team can generate course curricula (including sample assessments) fairly rapidly using a concept-based curriculum model. From the perspective of instructional materials, teachers' favorite or existing units, topics, lessons, and materials can almost always be accommodated by the choice of context/topic in the curriculum plan. When teachers begin a reform effort using familiar materials, the transition to instructional materials that are more conducive to teaching deep conceptual understanding can be taken at a feasible pace. Flexible, self-directed, inquiry processes become a dominant feature of the classroom. They are the most effective means of connecting the concept and context dimensions during any meaningful transfer of knowledge. Many secondary teachers' desire for content rigor is reflected in the precision and problem solving power of the curriculum's conceptual dimension.

COURSE CURRICULUM DOCUMENTS

The final curriculum document for each course of study has two parts:

1. A one-page **CURRICULUM SUMMARY** outlining
   A. units and unit durations
   B. concepts, topics, and skills for each unit.

2. A **CURRICULUM PLAN** that includes the information from the Curriculum Summary as well as
   A. mandated standards matched for each unit
   B. generalizations for concepts required by each unit
   C. sample assessments for required skills.

COURSE

Each unit is described with a **UNIT PLAN** document that connects the Curriculum Plan with the syllabus of lessons organized into a Learning Cycle.

UNIT

At the smallest scale, a **LESSON PLAN** describes the instructional or assessment activities that students engage in for learning.

LESSON

CURRICULUM SUMMARY

COURSE OF STUDY: **GRADE LEVEL(S):** **PERFORMANCE LEVELS(S):** **DATE:**

(Note: Use bold lines to indicate quarters)

Time (wks)			CONCEPT (Unit name in bold)	SKILL (Introduce/Reinforce/Master)	TOPIC (Unit name in bold)
B	CP	H			
			TOTALS		

CURRICULUM SUMMARY

COURSE OF STUDY: EARTH SCIENCE GRADE LEVEL: 10

Time (wks) B	Time (wks) C P	Time (wks) H	CONCEPT (Unit names in bold)	SKILL (incl. I/R/M)	TOPIC (Unit names in bold)
5	3	3	1. **PROPERTY/** MEASUREMENT	EXPER. METHOD (M); OBSER-VATION (M); CONTROLLED EXPERIMENT (R/M)	Ozone layer; Earth's layers (incl lithosphere, hydrosphere, biosphere, atmosphere) & Tectonic plates; Planets and astronomical bodies, incl. star layers. Weather properties: precip., temp, pressure, wind speed/ direction, humidity, pollution. BASIC: EM spectrum, Doppler effect. Teacher's Choice: Atmosphere layers, Water sources and quality, Fossils, Isotherms/isobars on maps
3	3	3	2. **LOCATION, DIRECTION,** SCALE • Grid system; Latitude and longitude		Ring of fire (earthquakes, volcanoes) and mountains; Abundant natural resources (air, water, soil, minerals); Wind (compass) directions
0	3	0-1	3. Teacher's choice: **SHAPE**		Continental drift; Topographical maps; Teacher's Choice: Galaxies, Galaxy walls and shape of the universe.
0	3	3-4	4. **WAVES**, DOPPLER EFFECT		The electromagnetic spectrum: everyday technologies, astronomical observations; Properties of sound; Tsunamis, ocean waves Teacher's choice: Seismology and the Earth's internal structure
6	1-2 2-4	4	5. CHANGE/ **PROCESS**	Teacher's choice: Trial & Error **(I)**	Ozone depletion; Plate tectonics (earthquakes, volcanoes, mountain building); Weathering, erosion, sedimentation; Teacher's choice: Star formation and evolution
3	3	3	6. **CYCLE**		Conservation and recycling of natural resources; Water, rock and carbon cycles**,** incl. the buildup of atmospheric CO_2.
2	3	0-2	7. Teacher's choice: **TIME**, EVENT SEQ., RATE		Geological history (fossils and geological profiles); Speed of light and observations of early universe.
5	4	4	8. **ENERGY** TRANS-FORMATION		Fossil fuels; Energy in water cycle; Wind, solar thermal, solar photovoltaic, geothermal, bio-fuel energy systems; Teacher's choice: Electric generators, motors, turbines, engines; Fission/Fusion (stars, nuke plants, neucleo-synthesis)
3	3	3-4	9. **HEAT** TRANSFER		The seasons; Global and local wind generation; Ocean currents; Regional climate variations; Global warming. Teacher's choice: Mantle convection
3	3	3-4	10. **MOTION AND FORCES**	EXPER. METHOD (M); OBSER-VATION -M-; CONTROLLED EXPERIMENT (R/M); Teacher's choice: Trial & Error **(R/M)**	Day/night, moon phases, eclipses, leap year; Earth's orbit and axis orientation correlated with seasons; Ocean tides; Weight differences due to gravity differences; Gravity as the important force in astronomy (shape of stars, planets, galaxies, universe expansion/contraction); Everyday linear motion. Teacher's choice: Earth's magnetic field; the magnetic striping on the ocean floor;
30	31-34	26-32	**TOTALS**		

The following curriculum summary was the first rendition created by the 6 Biology teachers at an urban high school of about 1500 students. The plan was followed for the first year that the curriculum was implemented.

CURRICULUM SUMMARY

COURSE OF STUDY: BIOLOGY GRADE LEVEL: 9

Time (wks)				CONCEPT (Unit names in bold)	SKILL (incl. I/R/M)	TOPIC (Unit names in bold)
B	CP	H	HH			
3	3	3		1. **LANGUAGE OF SCIENCE**, ENTITY - 3 wks -	EXPER. METHOD (M) OBSER-VATION (M)	Plan, animal, and bacterial cells
3-4	3	3		2. **PROPERTY**/ MEASUREMENT - 3 wks -		B: 3 of 4 Blood, Gastric juices, Soil enzymes. Inherited traits
3	3	2	2	3. **SCALE** - 3 wks -		Common materials, Radioactivity, DNA, Proteins, Teacher choice: Plastics, Slime
3-5	3	3		4. CHANGE/ **PROCESS** - 3 wks -	CONTROLLED EXPERIMENT (R/M)	Meiosis, Mitosis Plant growth Teacher's choice: Changes in fat cells over life. Nitrogen and Oxygen cycles
0-3	3	3		B, HH: Teacher's choice 5. **INTER-DEPENDENCE**, HABITAT, NICHE CONSERVATION, RESTORATION - 3 wks -		Selected Biomes and effects of Gnhs Effect. Selected food chains
3	3	2		6. **FORM AND FUNCTION** - 3 wks -		Human cells, Cell membrane Organ systems (incl. The immune system) High Honors: (?) Structure of DNA
4	4	4		7. **ENERGY** TRANS-FORMATION, CONSERVATION OF ENERGY - 4 wks -		Photosynthesis Human body (metabolism, respiration) Food chains Various energy transformations in cells of many different forms and functions Effects of radiation on organisms
6	6	6		8. REPRODUCTION, HEREDITY, CODE/**GENETICS** - 6 wks -		Pea plants Humans
3	3	3		9. **EVOLUTION**, VARIATION, ADAPTATION, EXTINCTION - 3 wks -	CONTROLLED EXPERIMENT (R/M) EXPER. METHOD -M- OBSER-VATION -M-	Fossils, Anatomy Embryology (ontogeny recapitulates phylogeny) Molecular evidence The changes induced by the greenhouse effect on different biomes
28-34	31	30		**TOTALS (wks)**		

Here is a copy of the Curriculum Summary that the 6 biology teachers marked up over a one hour meeting at the end of the first year of implementing the Biology curriculum. Throughout the first year of implementation, the teachers used post-it notes on a master copy of the Summary to keep track of suggestions for changes. At the end of the school year they quickly agreed to substantial changes. Such changes can be quickly made with broad agreement within the structure of a Curriculum Summary.

CURRICULUM SUMMARY

COURSE OF STUDY: BIOLOGY GRADE LEVEL: 9

Time (wks)				CONCEPT (Unit names in bold)	SKILL (Introduce/Reinforce/Master)	TOPIC (Unit names in bold)
B	CP	H	HH			
3	3	3	3	1. **LANGUAGE OF SCIENCE**, ENTITY L.O.S (1)	~~Dissection~~ microscope; EXPER. METHOD (M); OBSER-VATION (M)	Plan, animal, and bacterial cells. ~~Dissection: body systems, organs, tissues, cells.~~ characteristics of life
3-4	3	3	3	~~2. PROPERTY~~/ MEASUREMENT HH: CONCENTRATION	Exp. method stg 2: Data measurement and recording (M). ~~HH: Centrifuge use (M)~~	~~BASIC: 3 of 4~~ ~~Blood, Gastric juices, Soil enzymes,~~ ~~Inherited traits.~~ essential bio- HH: Cellular transport atoms elements biosph
~~3~~ 5	~~3~~ 5	~~2~~ 4	~~2~~ 4	3. **SCALE** (2)	HH: Electrophoresis (M) chemical models EKPOPCS, monomers/poly	Common materials, ~~Radioactivity,~~ chem, DNA, Proteins hierarchy of life, pH Teacher choice: Plastics, Slime
3	3	3	3	4. CHANGE/ **PROCESS** (3)	CONTROLLED EXPERIMENT (R/M)	Meiosis, Mitosis; ~~Plant growth;~~ Nitrogen and Oxygen cycles. Teacher's choice: Changes in fat cells over life. [CAPT lab - tiny bubbles]
3	3	3	~~2~~ 3	B, HH: Teacher's choice 5. **INTER-DEPENDENCE**, HABITAT, NICHE CONSERVATION, RESTORATION (8)		Selected Biomes and effects of Gnhs Effect. ~~Selected food chains~~
~~3~~ 5	~~3~~ 5	~~2~~ 5	~~2~~ 5	6. **FORM AND FUNCTION** (4)	Dissection	Human cells, diffusion, osmosis Cell membrane, buffers, enzymes Organ systems (incl. The immune system) [CAPT lab - apple sauce]
~~4~~ 3	~~4~~ 3	~~4~~ 3	3	7. **ENERGY** TRANS-FORMATION, CONSERVATION OF ENERGY (6)		Photosynthesis Human body (metabolism, respiration) Food chains + webs Various energy transformations in cells of many different forms and functions Effects of radiation on organisms
~~6~~ 4	~~6~~ 4	~~6~~ 4	~~6~~ 4	8. REPRODUCTION, HEREDITY, CODE/**GENETICS** (5)		Pea plants pedigrees, punnett square Humans transcription, translation, replication ~~HH~~: DNA protein synthesis
0	0	0	2	9. FORM & FUNCTION GENETICS		
~~3~~ 4	~~3~~ 4	~~3~~ 4	~~3~~ 4	10. **EVOLUTION**, VARIATION, ADAPTATION, EXTINCTION (7)	CONTROLLED EXPERIMENT (R/M)	Fossils, Anatomy Embryology (ontogeny recapitulates phylogeny) Molecular evidence The changes induced by the greenhouse effect on different biomes
0	0	0	~~3~~	Combination of concepts from units 1 → 9	EXPER. METHOD -M-; OBSER-VATION -M-	HH: FORENSICS
28-34	31	30	30	**TOTALS (wks)**		

Here is the revised Curriculum Summary that was implemented by the Biology teachers in the second year.

CURRICULUM SUMMARY

COURSE OF STUDY: BIOLOGY GRADE LEVEL: 9

Time (wks)				CONCEPT (Unit names in bold)	SKILL (Introduce/Reinforce/Master)	TOPIC (Unit names in bold)
B	**CP**	**H**	**HH**			
3	3	3	3	1. **LANGUAGE OF SCIENCE**, ENTITY, PROPERTY	Microscope use Exp. method stg 2: Data measurement and recording (M). **EXPER. METHOD (M)** **OBSER-VATION (M)**	Characteristics of life; Plant, animal, and bacterial cells; Senses versus properties.
5	5	4	4	2. **SCALE**	HH: Electrophoresis (M)	Hierarchy of life: elem. particles to isotopes to molecules to biosphere; Ph; Classification: Kingdom to species; Essential bio. entities: gene, DNA, Proteins, … , monomers, polymers. Teacher choice: Plastics, Slime
3	3	3	3	3. CHANGE/ **PROCESS**	CAPT lab: Tiny bubbles **CONTROLLED EXPERIMENT (R/M)**	Mitosis; Nitrogen and Oxygen cycles.
5	5	5	5	4. **FORM AND FUNCTION** CONCENTRATION	Dissection. CAPT lab: Apple Sauce	Human cells of different tissues; Cell membrane, diffusion, osmosis; Enzymes; Organ systems (incl. the immune system), with fetal pig as example.
4	4	4	4	5. REPRODUCTION, HEREDITY, CODE/**GENETICS**		Pea plants & humans: pedigrees, Punnett squares; DNA: Transcription, translation, replication, protein synthesis; Meiosis.
3	3	3	3	6. **ENERGY** TRANS-FORMATION, CONSERVATION OF ENERGY		Photosynthesis Human body (metabolism, respiration) Food chains and webs Various energy transformations in cells of many different forms and functions Effects of radiation on organisms
4	4	4	4	7. **EVOLUTION**, VARIATION, ADAPTATION, EXTINCTION	**CONTROLLED EXPERIMENT (R/M)**	Fossils, Anatomy Embryology (ontogeny recapitulates phylogeny) Molecular evidence The changes induced by the greenhouse effect on different biomes
3	3	3	3	8. **INTER-DEPENDENCE**, HABITAT, NICHE CONSERVATION, RESTORATION		Selected Biomes and effects of Gnhs Effect.
0	0	0	3	**9.** Combination of concepts from units 1 → 8	**EXPER. METHOD -M-** **OBSER-VATION -M-**	**HH: FORENSICS**
30	30	29	29	**TOTALS (wks)**		

CURRICULUM SUMMARY

COURSE OF STUDY: CHEMISTRY **GRADE LEVEL:** 10 + elective mix **DATE:** 6/05

(Note: Bold lines indicate quarters)

Time (wks) CP	H	HH	CONCEPT (Unit name in bold)	SKILL (Introduce/Reinforce/Master)	TOPIC (Unit name in bold)
4	3	3	1. **PROPERTY** SCALE, NUMBER, COMPOSITION, CHEMICAL ENERGY (E_{ch} at bulk scale) - Compounds, elements, mixtures at bulk and molecular scales - The mole	EXPER. METHOD (R, M) OBSER-VATION (R, M)	- Fields of science; Definition of chemistry - Nanotechnology - Periodic table: properties of atoms/isotopes/ions, the scale of an atom - Alloys, chromatography, blood, milk, river water - senses of smell, taste, color & % composition of both mixtures and molecules: flavorings and perfumes - Composition changes: iron & sulfur, light sticks - Counting large numbers: sand grains, stars, grass, etc - Teacher's choice: Distillation e.g. wood, crude oil refining
2	2	2	2. POROSITY, MASS, **DENSITY**	CONTROLLED EXPERIMENT (R, M)	Hook: Column of floating liquids and solids - Diffusion of air and helium through balloon skin - Mass changes when burning paper, magnesium - Mass & density changes with rusting; - Density of atoms, isotopes, and their elements
3	3	3	3. KINETIC THEORY OF **MATTER**, TEMPERATURE PHASE, THERMAL ENERGY	EXPER. METHOD (M) OBSER-VATION (M)	- Hook: Phase of common materials; Silly putty; Ooblek; slime - Phase changes of precipitation (frost, sublimation, etc), cloud formation (vapor trail) & molecular properties that determine phase. - Comparative melting points; latent heat of fusion and vaporization at both bulk & molecular scales applied to meteorology - H/HH teacher's choice: biological sensation of "heat"
2	2	2			
3	3	3	4. **CONCENTRATION** - percentage composition - colligative properties SOLUBILITY diff. solvents with diff. substances		- pH: acids, bases, salts - Water resources (ChemCom: Fishkill unit), - Oxygen and salt concentrations in water (CBL Probes) - Auto emissions, atmospheric concentrations (e.g. CO_2) - Making ice cream - Dissolving peanuts in water or acetone
4	4	4	5. **CHEMICAL REACTION** - stoichiometry - nomenclature ENERGY TRANSFORMATION		Hook: Reaction of lead nitrate and potassium chromate -Common reactions: digestion and antacids; making soap, flavorings; luminol (light stick) - Reaction pathways of alcohol in human body - Combustion/respiration, Photosynthesis - "Hot packs," "Cold packs" - Poisons, toxins, drugs
4	4	4	6. CONFIGURATION, **BONDING,** CHEMICAL ENERGY (E_{ch} at molecular scale)		- Electron configurations - Hydrocarbon molecules - Geometric (cis/trans) isomers - Glues - HH: stereo isomers
3	3	3	H/HH: 7. **KINETICS,** FREE ENERGY		- Biological catalysts - Auto and pollution catalytic converters
3	3	3	H/HH: 8. CHEMICAL **EQUILIBRIUM**		
4	4	4	9. **CORRELATION**	CONTROLLED EXPERIMENT (M)	- Everyday applications (Cartesian diver, breathing); - Gas laws applied to meteorological phenomena
32	31	31			

CAPT →

Total

CURRICULUM PLAN

SUBJECT/COURSE: ______________________________ **GRADE(S):** ____________________ **STUDENT PERFORMANCE LEVEL(S):** ________________ **DATE :** ___________

UNIT - **Duration**	**TRANSFERABLE CONCEPT(S)**	**TOPIC(S)**	**SKILL(S)** (**I**ntroduce/**R**einforce/**M**aster)	**STANDARD(S)** Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	**ENDURING UNDERSTANDINGS OR SAMPLE PERFORMANCE ASSESSMENT TASKS**

Z

CURRICULUM PLAN

SUBJECT/COURSE: BIOLOGY GRADE: 9 DATE : 5-31-04

UNIT - Duration	TRANSFERABLE CONCEPT(S)	TOPIC(S)	SKILL(S) (Introduce/Reinforce/Master)	STANDARD(S) Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS
1. LANG-UAGE of SCIENCE All levels: 3 wks	LANGUAGE OF SCIENCE ENTITY PROPERTY • Acid & Base and pH values	Characteristics of life; Plant, animal, bacterial cells; Senses versus properties. Teacher's Choice: HOOK: Nature of Lichens; GAIA hypothesis. - or – Live termites	Microscope use. This unit: Sci method stg 2: Data measurement and recording (M) Experimental method (M) Observation (M) Both exp. Method and observation are continued throughout the year	Describe the basic similarities and differences found in the structures of plant, animal and bacterial cells.	LANGUAGE OF SCIENCE, ENTITY: 1. The natural world is imagined as delineated into things and composed of substances which we think of as discrete entities and that we identify with names: What is it? Observation of the natural world begins by delineating it into named things, objects, substances, materials, or systems, meaning that we draw an imaginary line around each to identify it and separate it from its environment, and then give it a name. 2. The entities that make up the natural world are described and differentiated in terms of their properties. Things, objects, substances, materials, and/or systems are distinguished from each other and from their environments by observing and comparing their properties. 3. The changes that occur throughout the natural world are described in terms of property changes: What happened? PROPERTY: 1. Observations of the natural world describe properties of objects, substances, or waves (i.e. entities) by stating, measuring, or approximating the values of chosen properties, while other properties (e.g. time, direction, probability) describes processes and events and others (e.g. force, pressure) describe interactions between entities. 2. Every property has many possible values, often and preferably numerical, that are along a continuum, range or scale that tells how little-much, weak-strong, or low-high the property measures in a particular case.

UNIT - Duration	TRANSFERABLE CONCEPT(S)	TOPIC(S)	SKILL(S) (Introduce/Reinforce/Master)	STANDARD(S) Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS
(cont.) LANG-UAGE of SCIENCE All levels: 3 wks	Continued: LANGUAGE OF SCIENCE ENTITY PROPERTY • Acid & Base and pH values				3. A property's measured value depends upon which of many different possible units of measure are used, although each unit in turn goes with only one property (regardless of which name the property happens to be labeled within the particular context in which it is being used). EXPERIMENTAL METHOD (M): Students create and write a 4-stage lab report choosing and implementing appropriate sub-sections for investigations based on observations, simulations (e.g. magnitude of a mole), and controlled experimentation. OBSERVATION (M): Students choose and specify accurately and clearly the values of at least two non-numerical and three numerical properties that are appropriate for the question or context. MICROSCOPE USE : "Choose an appropriate objective lens magnification matched to the size of the entity being observed."

UNIT - Duration	TRANSFERABLE CONCEPT(S)	TOPIC(S)	SKILL(S) (Introduce/Reinforce/Master)	STANDARD(S) Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS
2. SCALE B, CP: 5 wks H, HH: 4 wks	SCALE	Hierarchy of matter: elem. particles, atoms, isotopes, ions, molecules, monomers, polymers. bulk-scale things; Hierarchy of life: molecules to biosphere. Essential biological entities: carbohydrates, fats, proteins; amino acids, bases, genes, DNA, RNA, chromatid, chromosomes. Ions and Ph; Classification of life: Kingdom to species; Teacher choice: Plastics, Slime	HH: Electrophoresis. Continued from above: Experimental method (M) Observation (M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks)	**Describe how genetic materials are organized in genes and chromosomes in the cells of living organisms.** Describe the basic structure of atoms (including protons, neutrons and electrons) and how the atoms of one element are alike and different from each other. **Describe the organization of the elements in the periodic table *(i.e. by atomic number),*** including the properties and electronic arrangements of elements in the first three periods. **Explain the differences among atoms, elements, molecules**, compounds and mixtures and give examples of each using common materials. I(c) **Describe** how radioactive **isotopes** spontaneously decay to produce different atoms and emit radiation. III(c) **Describe** the general structure of **DNA** and how it is transcribed to **proteins** that carry out the cell functions. IV(d) Explore how simple monomers are combined to create plastics (e.g., polyethylene, polyvinyl chloride, polystyrene).	1. A thing or object's size describes how big or small it is compared to something else, often the human body. 2. All bulk-scale things are made up of molecules, which are made up of atoms, which are made up of elementary particles, which are, finally, made up of leptons, creating a hierarchy of matter. 3. The five levels of the hierarchy of matter differ [not only] in their scale, … TEACHER'S CHOICE: … but also in their behavior: each of the levels behaves in unique and distinct ways. 4. All living organisms are structurally organized hierarchically, beginning with cells that are bulk objects made up of many different molecules of only four distinct types: carbohydrates, fats, proteins, and nucleic acids. Many of the same cells together form a tissue, and different tissues together form an organ, several of which function together to form an organ (body) system, all of which work together to create the living organism. Most organisms group themselves into families, populations, and communities, which interact with the physical environment to form ecosystems. All the ecosystems of a planet together form a biosphere. 5. HH: ELECTROPHORESIS Students use correct technique to carry out an electrophoresis.

UNIT - Duration	TRANSFERABLE CONCEPT(S)	TOPIC(S)	SKILL(S) (Introduce/Reinforce/Master)	STANDARD(S) Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS
3. PROCESS All levels: 3 wks	CHANGE/PROCESS	Mitosis; HH: regulatory mechanisms of cell growth. "Tiny Bubbles" CAPT lab: yeast breakdown of hydrogen peroxide; Nitrogen and Oxygen cycles (at both molecular and bulk scales) with focus on biological importance. Teacher's Choice: HOOK: Normal versus cancerous growth.	Controlled Experiment (R/M) The controlled experiment skills are continued from here on throughout the year. Continued from above: Experimental method (M) Observation (M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks)	Students understand that cells divide for growth of the organism, repair and reproduction. • Describe the process of mitotic cell division and explain how this process is important in growth of the organism and repair of tissues. • Describe the process producing reproductive cells (meiosis) in females (egg cells) and males (sperm cells). **• Describe the oxygen,** carbon **and nitrogen cycles and explain their significance**. *[Carbon cycle is allocated to Integrated Science.]*	CHANGE/PROCESS: 1. All changes, processes, events and actions involve entities (things, substances or waves). 2. During any change, properties of the involved things/substances/waves change values or, if the change consists of comparing different things/substances/waves (i.e. a change in perspective), the same property may have different values for the different entities. 3. The changes in property values that occur during any process or event always take time. 4. Complex events and processes can often be simplified by dividing t hem into a sequence of shorter duration changes that occur one after the other. 5. A cycle is a repeating pattern of change(s)n in one or more properties of one or more substances or things. 6. Processes and changes are driven by energy transformations and transfers, and even cycles require new energy inputs from outside to continue. CONTROLLED EXPERIMENT (M): 1. Students will describe, identify, give examples of, and compare experimental situations that are observations and those that are that are controlled experimentation. 2. Students will identify controlled, dependent, and independent variables for questions in a wide variety of experimental situations. 3. Given the same experimental context, students will be able to formulate questions that imply different combinations of dependent, independent, and controlled variables. 4. Students will describe and give examples of the difference in experimental situations where controlled variables are appropriate and where a control is appropriate. 5. Students will carry out a controlled experiment, analyzing the results to establish and describe the correlation between the dependent and independent variables.

UNIT - Duration	TRANSFERABLE CONCEPT(S)	TOPIC(S)	SKILL(S) (Introduce/Reinforce/Master)	STANDARD(S) Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS

4.. FORM AND FUNC-TION All levels: 5 wks	**FORM AND FUNCTION** C0NCENTRATION	Human cells of different tissues; Cell membrane, diffusion, osmosis; Enzymes; Organ systems (incl. the immune system), with dissected fetal pig as major exemplar. Teacher's Choice: HOOK: Maple tree sap, sugar formation by tree, and production of concentrated maple syrup.	Dissection Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)	• Describe the structure and explain the main functions of skin, nerve, muscle and blood cells. • Explain how the cell membrane helps the cell to maintain its unique internal composition. Students understand the healthy functioning of the human body and how environmental conditions, nutrition, physical activity and pathogens affect its functioning. • Describe the structure and function of the major human organ systems (e.g., circulatory, respiratory, digestive, reproductive and nervous systems). **• Explain the role of nutrients and physical activity in the functioning of the human body.** • Explain the human body's defense system against infectious diseases and the role of antibiotics and vaccinations.	FORM AND FUNCTION: 1. Different organisms and designed entities have features that help them function and thrive in different niches and ecosystems. 2. A species' (or designed entity's) physical characteristics, especially size, shape, configuration, and composition, as well as its particular processes of growth/construction, development, and behavior/use, are dictated by the patterns of interaction between it and other organisms/entities and the physical environment; i.e. form follows function. 3. Dimensional properties, such as total surface area, length-to-width ratio, and the ratio of an entity's surface area compared to its volume, are major criteria and constraints for what it does and how it operates, including its internal processes, life processes in the case of organisms, and the processes it carries out and in which it is involved. CONCENTRATION: 1. A mixture of two or more substances can be made by combining almost any amount (i.e. mass, volume, number) of each, and concentration measures the amount of one ingredient compared to the amount of the other(s). 2. Concentration compares the number, mass, or volume of one component in a mixture to the number, mass, or volume of the other component(s) or of the mixture as a whole along a continuum that ranges from concentrated to dilute. 3. The degree to which two substances will mix and stay mixed depends upon the strength and pattern of the forces between their respective molecules. 4. Within a fluid mixture that contains localized differences in concentration, particles will move and spread to create a uniform concentration throughout the mixture, the rate of such diffusion depending upon the relative particle sizes, their masses, the temperature of the mixture, and any mixing mechanisms that might be operating (e.g. stirring, convection). 5. Differences in concentration between adjacent fluid mixtures can be created or maintained by intervening mechanisms (e.g. membranes, filters) that can distinguish and select from among the different particles in the mixtures.

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5. GENETICS All levels: 4 wks	REPRODUCTION, HEREDITY CODE/GENETICS	Pea plants & humans: pedigrees, Punnett squares; DNA: Transcription, translation, replication, protein synthesis; Meiosis.	Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)	• Explain how genes are related to inherited traits and how genes can be manipulated by modern technologies. • Explain how the genetic information from both parents is mixed in the fertilized egg to produce an individual with new combinations of genes and traits. Students understand how each organism carries a set of instructions (genes composed of DNA) for specifying the components and functions of the organism.	REPRODUCTION, HEREDITY • inherited traits, succession, pedigree 1. Offspring inherit those traits of their parents that are coded and transmitted through genetic material during reproduction, with each progeny acquiring a random mix of traits from each parent resulting from the mixing of coded messages from each parent. 2. When two different coded messages for the same trait are expressed, sometimes the value for that trait is derived entirely from one or the other message, sometimes both values are expressed in varying proportions (incomplete dominance), and sometimes the messages are blended to create a new and different value for the trait (co-dominance). 3. Organisms that reproduce asexually divide into two, so the offspring each receive the same coded information and are identical to the parents and each other. CODE/GENETICS 1. Coding systems are translated with a one-to-one correspondence between the coded and expressed units, each being translatable into the other. 2. Unlike representations such as drawings, plans, or descriptions, codes require some intervening mechanism or translation for the coded information to be expressed into its intended product, which rarely resembles the original code in any significant way. 3. A master code repository containing complete information is often protected from its environment to reduce harmful effects that could change the coded information, with temporary copies being made and moved to various locations for the purposes of translation and/or expression. 4. Any process of replication, translation or expression of coded information inevitably involves some loss or corruption of the original code, and systems that rely upon such processes usually have some method of self-correction or checking.

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6. ENERGY All levels: 3 wks	ENERGY TRANSFORMATION CONSERVATION OF ENERGY	Photosynthesis Metabolism, cellular respiration, and heat production in endo/ecto/poikilo-therms. Food chains and webs Various energy transformations in cells of many different forms and functions Effects of radiation on organisms, at molecular, cellular, and tissue scales.	Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)	• Explain how carbon dioxide and water are converted into energy-rich foods through an energy-capturing mechanism (photosynthesis). • Describe the transfer of energy from the sun to the environment and back to space, through food webs consisting of producers, consumers and decomposers. **Describe different classifications within the electromagnetic spectrum in terms of their** wavelengths, **energies, effects on living organisms** and uses in modern technologies. *(also allocated to integrated science)* **• Explain the role of nutrients and physical activity in the functioning of the human body.** **Explain that total** mass and **energy are conserved in synthesis and decomposition reactions.** III(b) **Explore and explain** matter and **energy transformations in photosynthesis and cellular respiration.**	ENERGY 1. Because energy is a property that is conserved during any process or event, it seems to have the quality of a fluid that flows from container to container even though it is not a material or substance. ENERGY FORMS AND TRANSFORMATIONS 1. An entity can contain energy in many different ways, called the forms of energy, depending upon its physical and chemical properties, what it happens to be doing, and its location. 2. Energy is transferred between and among entities, some losing and some gaining, and the transferred energy is often transformed from one form of energy to another. Changes and processes can often be usefully described in terms of their input and output energy forms. TEACHER'S CHOICE: 3. Energy transfers and transformations occur in never-ending chains and webs of inputs and outputs that can be described with many different beginnings and ends, at many different scales (from the atomic to macroscopic) and at varying levels of detail, depending upon the problem or question being considered. CONSERVATION OF ENERGY: 1. When energy flows between and among entities, the total amount of energy at the beginning of the process is equal to the amount at the end, with the losses of energy by some entities equaling the gains made by others.

UNIT - Duration	TRANSFERABLE CONCEPT(S)	TOPIC(S)	SKILL(S) (Introduce/Reinforce/Master)	STANDARD(S) Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS
7. EVOL-UTION All levels: 4 wks	EVOLUTION	Fossils, Anatomy Embryology (ontogeny recapitulates phylogeny) Molecular evidence The changes induced by the greenhouse effect on different biomes	Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)	Students understand that the basic idea of biological evolution is that the Earth's present-day species developed from earlier species. • Explain how environmental changes can lead to the extinction and evolution of species. • Describe how fossils and anatomical evidence provide support for the theory of evolution. **• Explain how organisms are adapted to environmental conditions in different biomes.**	1. All organisms are related to one another to varying degrees since every species has developed from some other species and thus any two species share common ancestors at some time in the past. 2. Gradual changes in a population's environment result in changes from generation to generation in its traits such that the population's individuals are better able to survive and reproduce in the new environment. (Note: A population is a group of organisms that are all of the same species and all of which could mate with each other.) 3. The heritable changes that occur from generation to generation of a population are selected from among the variations in heritable traits that exist within any population. 4. Environmental changes, including changes in resources, climate and surrounding waves (e.g. radiation, sound, vibration), often create changes in a species' shape, configuration, size, color, composition, behavior, manner of taking in, using, conserving, and expelling energy and materials, and/or manner in which it senses its environment. 5. The variations in a population that develop over the life spans of individuals, even those due to environmental change, cannot be passed to offspring, while those variations in traits that are inherited cannot develop or change during an individual's life time. 6. Variations due to both sexual reproduction and/or mutation may enable individuals to survive and/or reproduce better than others in a changing environment.

UNIT - Duration	TRANSFERABLE CONCEPT(S)	TOPIC(S)	SKILL(S) (Introduce/Reinforce/Master)	STANDARD(S) Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS
(cont.) Evolution	Continued: EVOLUTION VARIATION, ADAPTATION EXTINCTION		Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)		7. The pool of different gene versions, and therefore variations in a particular trait, within a population can change due to migrations of individuals in or out of the population and changes in the environment. 8. Large populations can shrink rapidly and even disappear before being able to evolve when subjected to rapid environmental changes that severely reduce their habitat (e.g. climate change, agriculture), their number (e.g. predators, human exploitation, food competition), or their ability to survive and reproduce (e.g. disease). 9. Large populations can shrink rapidly and even disappear before being able to evolve when subjected to rapid environmental changes that severely reduce their habitat (e.g. climate change, agriculture), their number (e.g. predators, human exploitation), or their ability to survive and reproduce (e.g. disease). TEACHER'S CHOICE: 10. The frequency of different variations of a particular trait within a large, sexually-reproducing population will remain constant from generation to generation if no environmental changes occur to create a selection pressure that favors one variation over another. (i.e. Hardy-Weinberg) TEACHER'S CHOICE: 11. Because small populations tend to have large variations in birth and death rates, it is likely that low birth and high death rates will eventually coincide and the population die out, particularly since many environmental conditions, such as severe weather and disease, foster both trends. TEACHER'S CHOICE: 12. Because small populations tend to have large variations in birth and death rates, it is likely that low birth and high death rates will eventually coincide and the population die out, particularly since many environmental conditions, such as severe weather and disease, foster both trends.

UNIT - **Duration**	**TRANSFERABLE CONCEPT(S)**	**TOPIC(S)**	**SKILL(S)** (**I**ntroduce/**R**einforce/**M**aster)	**STANDARD(S)** Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	**ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS**
8. INTER-DEPEN-DENCE All levels: 3 wks	INTERDEPENDENCE	Selected Biomes (and effects due to Gnhs Effect)	Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)	Explain how changes in resources, predation and climate can affect the growth of different populations. Explain how organisms are adapted to environmental conditions in different biomes. Explain how human activity can impact the stability of various ecosystems.	INTERDEPENDENCE: • predator/prey, food chain/web, symbiosis: parasitism, commensalisms, mutualism 1. A change in any part of an inter-connected system of entities usually produces a change, either directly or indirectly, in the other part(s),… TEACHER'S CHOICE: … and these effects are often separated in both space and time from the original cause. 2. Every thing, system, or event is affected by changes in its environment, while the environment is likewise affected by the changes in the thing, system, or event. Thus an environmental or climactic influence on an ecosystem can induce a change in the populations within the ecosystem community. 3. All organisms depend upon their immediate physical environment (habitat) for the shelter, protection, food, water, energy, and waste disposal needed to survive, reproduce and prosper. 4. Different ecosystems often include similar patterns of interactions and dependencies among its parts, such as the cycling of materials or, within a community of organisms, such as predator/prey, food chains and webs, parasitism, symbiosis, and commensalism. 5. Every population within an ecosystem occupies a unique niche, characterized by a unique set of interactions with and dependencies upon other organisms and the physical environment that satisfies its needs for survival, reproduction, and prosperity. 6. When there is no cost to individuals for using a shared but limited resource, individual self-interest leads each to consume more than can, in total, be sustained without depleting the resource, yet no individual is inclined to reduce consumption at his/her own expense to the benefit of the remaining users. (This concept is know as the *Tragedy of the Commons*.)

UNIT - **Duration**	**TRANSFERABLE CONCEPT(S)**	**TOPIC(S)**	**SKILL(S)** (**I**ntroduce/**R**einforce/**M**aster)	**STANDARD(S)** Standards in bold are repeated under other concept(s). Bolded parts apply to the designated unit.	**ENDURING UNDERSTANDINGS or SAMPLE PERFORMANCE ASSESSMENT TASKS**
(cont.) INTER-DEPEN-DENCE	Continued: INTERDEPENDENCE		Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)		TEACHER'S CHOICE: 7. In order to minimize the effect on an ecosystem of human's disproportionate use of resources, they may reduce their consumption of resources, re-use resources multiple times before discarding them, re-cycle discarded resources into new or replacement products, or replace resources with others that have less environmental impact. CP, H, HH: 8. Exchanges of materials, energy, and information between systems or between systems and their environments can create a web of many interdependent changes that, within a stable ecosystem, is self-supporting and self-perpetuating. 9. The number of niches in an ecosystem is directly proportional to the diversity of habitats and organisms within it.
9. FOREN-SICS HH only: 3 wks	**ALL OF THE CONCEPTS LEARNED IN THE PRECEEDING UNITS 1 → 8 WILL BE COMBINED IN THIS UNIT.**	**Forensics**	Continued from above: Experimental method (M) Observation (M) Controlled Experiment (R/M) (See first unit, LANGUAGE OF SCIENCE, for sample performance assessment tasks for Experimental method and Observation. See PROCESS unit for sample assessment tasks for CONTROLLED EXPERIMENT.)		See all of the above enduring understandings.

LESSON PLAN TEMPLATE

(Spacing is intended for electronic use of this template. Alternately, attach additional paper as needed.)

TITLE: ______________________________

SUBJECT AREA: ____________GRADE LEVEL: __ COURSE NAME: ______________

DURATION: __________ UNIT OF STUDY: ______________________

STAGE OF LEARNING CYCLE (circle one):

hook	concept/skill formation	concept/skill expression	concept/skill transfer

BRIEF SUMMARY: (2-3 sentences describing major content, activities, expected results)

REQUIRED INSTRUCTIONAL RESOURCES:

TARGETED LEARNING OUTCOMES (CURRICULUM)

Specify the learning outcomes for the lesson:

1) TRANSFERABLE CONCEPT(S), GENERALIZATIONS. What do you want students to **understand**?

2) TOPIC, CONTEXT, INFORMATION, TEXT TITLE/GENRE, CONVENTIONS: What do you want students to **know**?

3) BASIC SKILLS, PROCEDURES, PROTOCOLS: What do you want students to learn to **do**? (Communication, Physical/Kinesthetic action, e.g. measuring, writing, mapping, Follow a scripted/repeated procedure, Use an algorithm.)

ASSESSMENT

ON-GOING ASSESSMENT: During and/or at the end of the lesson, what strategies will you use to monitor student learning progress? (Note: "*On-going*" refers to how each lesson fits within the unit plan that includes pre- and final assessments.)

INSTRUCTION

List a numbered sequence of activities, assignments or learning activities. Provide enough detail so a teacher teaching the lesson for the first time could follow the plan.

□ Include time durations for different phases and activities.
□ Include student grouping format/structure for each lesson segment.
□ Include a *Do-Now*. (A short activity at the beginning of the class intended to transition students to the learning mode, re-connect with the on-going flow of lessons, and orient them to the anticipated learning.)
□ Indicate where and when on-going assessment strategies will occur.
□ Attach referenced student assignment sheets and/or handouts, resource lists, etc..
□ Specify probable homework with scoring guide and/or rubric(s). (Actual homework often differs from the planned homework since lessons often change depending on student reactions.)
□ **For hook lesson(s):** Include an advance organizer introduction that connects the intended learning for the unit to prior learning as mapped within the master concept, skill, or topic structures.

	ACTIVITY, TASK, ASSIGNMENT	STUDENT GROUPING	TIME
1	**DO-NOW/WARM-UP:**		
2			
3			

COURSE CURRICULUM DESIGN IN A NUTSHELL

1. ANALYZE STATE FRAMEWORKS FOR CONCEPT, TOPIC, SKILL LOADS.
2. SUMMARIZE CONCEPTS, TOPICS, and SKILLS REQUIRED BY THE STATE.
3. SUPPLEMENT THE STATE REQUIRMENTS WITH ADDITIONAL CONCEPTS, TOPICS, and SKILLS AS DEEMED BEST.

> Small groups from each discipline work for about 6 - 12 hours.

4. ALLOCATE REQUIRED and SUPPLEMENTARY COMPONENTS TO INDIVIDUAL COURSES/YEARS.

> Teachers from all courses/years meet for 1-2 hours.

5. PLAN A SYLLABUS OF CONCEPTS/SKILLS AND TOPICS FOR EACH COURSE BY COMPLETING THE **CURRICULUM SUMMARY** DOCUMENT.
6. CHOOSE/GENERATE ENDURING UNDERSTANDINGS OR SAMPLE ASSESSMENTS FOR EACH UNIT
7. GENERATE THE COURSE **CURRICULUM PLAN** DOCUMENT

> Small groups for each course, working for 2 days, with only secretarial tasks remaining.

TOTAL TIME: A full-year high school science course typically requires 40-50 person-hours and about 20 secretarial hours to complete up to this point.

8. **UNIT DESIGN:** START BY WRITING PRE-/POST-ASSESSMENTS COMMON FOR ALL STUDENTS IN THE COURSE. THE UNITS ARE DESIGNED AROUND A LEARNING CYCLE, INCORPORATING EXISTING LESSONS AND RESOURCES AS MUCH AS POSSIBLE.

> Small groups work for 4-6 days (over summer?) to write units. Each unit takes about 20 person-hours.

9. **LESSON DESIGN:** COOPERATION IN DESIGN AND SHARING OF LESSONS AMONG TEACHERS VIA A NETWORKED DATABASE GREATLY FACILITATES THIS PROCESS AND CREATES A HIGH LEVEL OF COLLEGIALITY.

<u>**CURRICULUM PLANNING from MANDATED STANDARDS:**</u>
<u>**CHECK LIST**</u>

SUBJECT AREA: ________________ GRADE LEVEL(S)/COURSE(S): ____________
(First establish a sequence of steps, using numbers in the left column, appropriate for the subject area, grade levels or courses, and local circumstances.)

SEQUENCE (1,2, etc)	**ACTION**	**WHO**	**CHECK-OFF or DATES**	**NOTES**
	A. Establish a structure of transferable concepts.			
	B. Establish a list of skills.			
	C. Analyze and match each standard with its most useful concept and/or skill.			
	D. Choose *One-concept:Many-topic* or *One-topic:Many-concept* approach.			
	E. Re-organize standards according to the chosen approach and begin filling in **Curriculum Plan** document.			
	F. Match each concept and skill with a topic (including "teacher's choice") as indicated by the standards or as appropriate.			
	G. Summarize concepts, skills and topics in the **Curriculum Summary** document.			
	H. Choose supplementary concepts, skills, and/or topics, working with Curriculum Plan and Summary documents.			
	I. Choose or write generalizations for specified concepts, describe sample assessments for skills, specify topic information as needed.			
	J. Distribute the concepts, skills or topics to grade levels or courses covered by the mandated standards.			
	K. Use the Curriculum Summary to plan a syllabus of units with specified concepts, skills and topics for each grade level or course, including durations and ability groupings			
	L. Complete the Curriculum Plan document.			

IMPLEMENTING STATE CURRICULUM FRAMEWORKS

according to a concept-based model of curriculum

Curriculum Planning Procedure: (The exact sequence will vary with circumstances. The letter designations for each step correlate with those on the accompanying checklist)

A, B: Establish a structure of well-defined concepts and a sequenced list of skills.

C: Analyze each standard in the frameworks to determine if it is concept based or skill based. For each concept-based standard choose its most useful underlying concept(s). For each skill-based standard, identify its underlying skill(s).

D: Match each standard with a topic. Each standard, whether concept- or skill-based, should be matched with a topic. One option is to leave this choice up to individual teachers, in which case the curriculum document would state that the topic is a "teacher's choice."

E, F, G: a) Decide on whether your subject area and grade level will follow a one-concept, many-topic model or a one-topic, many-concept model.
b) Re-organize the standards for each grade cluster correspondingly. (i.e. according to skill and concept, or according to topic.)
c) Summarize the skills and concepts required by the frameworks, or the required topics, depending on which model was chosen in part (a).

G: Choose supplementary concepts, skills or topics that, although not required by the frameworks, will be required by the school district's curriculum.

H: Describe sample assessments for each standard. The State frameworks and "Guides to the MCAS" often give examples of assessment tasks and activities, and past test items are also available for many states.

I: Distribute the required concepts and skills to each grade level or course within the grade span covered by the frameworks. Each grade level or course would, on average, have responsibility for a few concepts. The concepts are inter-related, so learning one of them reinforces previously learned concepts and anticipates concepts to be learned later. Concepts organized from the general to specific refer to and reinforce larger-scale concepts that were learned even years prior (i.e. a spiral organization is built in). Simple concepts become the pre-requisites for more complex concepts to be learned later. There are many different sequences of concepts that would follow a pattern towards greater detail, more complexity and greater abstractness. Teachers chart a sequence that makes sense for their school.

J: Each grade level or course plans a syllabus of:
a) concepts and skills, both required and supplementary
b) required topics.

****

STEP ONE: Establish a structure of well-defined concepts and a sequenced list of skills.

Use learning theory, subject area texts and classroom experience to identify generic, definable concepts and skills that can be applied to a wide variety of problems and situations. Organize the concepts into a structure according to the three parameters of generality, complexity, and abstractness. Organize the skills into a sequence according to difficulty.

STEP TWO: Analyze each standard in the frameworks to determine if it is concept based or skill based.
a) for each concept-based standard choose its most useful underlying concept(s)
b) for each skill-based standard choose its most useful underlying skill(s)

Analyze the standards for the entire grade span covered in the frameworks. Most standards are quite clearly best approached from either the concept or skill perspective. However, there are standards for which either approach, or even both approaches, could be used. Most standards infer a most useful underlying concept or skill. Some standards might best be matched with more than one concept or skill. Other standards will need to be split, each part pertaining to a different concept or skill. Choose the best-fit concept from any of the levels within the conceptual structure.

Those standards that are primarily topic-based should be matched with a concept or a skill. An option is to leave this choice up to individual teachers, in which case the curriculum document would state that the concept or skill was a "teacher's choice."

STEP THREE: MATCH EACH STANDARD WITH A TOPIC.

Each standard, whether concept- or skill-based, should be matched with a topic. One option is to leave this choice up to individual teachers, in which case the curriculum document would state that the topic is a "teacher's choice."

STEP FOUR:

A) Decide on whether your subject area and grade level will follow a one-concept, many-topic model or a one-topic, many-concept model.
b) Re-organize the standards for each grade cluster correspondingly (i.e. According to skill and concept, or according to topic).
c) Summarize the skills and concepts required by the frameworks, or summarize the required topics, depending on which model was chosen in part (a).

A many-topic, many-concept/skill curriculum is also possible. The summary of skills and concepts should use the same format as the "master" concept structure or skill sequence produced in Step One.

STEP FIVE: CHOOSE SUPPLEMENTARY CONCEPTS, SKILLS OR TOPICS THAT, ALTHOUGH NOT REQUIRED BY THE FRAMEWORKS, WILL BE REQUIRED BY THE SCHOOL DISTRICT'S CURRICULUM.

Supplementary concepts, skills or topics can be added to those required by the frameworks. These supplements will be required curriculum, as distinct from "teacher choices" which may vary from teacher to teacher, year to year.

STEP SIX: DESCRIBE SAMPLE ASSESSMENTS FOR EACH STANDARD.

The State frameworks and Guides often give examples of assessment tasks and activities.

STEP SEVEN: DISTRIBUTE THE REQUIRED CONCEPTS AND SKILLS TO EACH GRADE LEVEL OR COURSE WITHIN THE GRADE SPAN COVERED BY THE FRAMEWORKS.

Each grade level or course would, on average, have responsibility for a few concepts. The concepts are inter-related, so learning one of them reinforces previously learned concepts and anticipates concepts to be learned later. Concepts organized from the general to specific refer to and reinforce larger-scale concepts that were learned even years prior (i.e. a spiral organization is built in). Simple concepts become the pre-requisites for more complex concepts to be learned later. There are many different sequences of concepts that would follow a pattern towards greater detail, more complexity and greater abstractness. Teachers chart a sequence that makes sense for their school.

STEP EIGHT: EACH GRADE LEVEL OR COURSE PLANS A SYLLABUS OF:
a) CONCEPTS AND SKILLS, BOTH REQUIRED AND SUPPLEMENTARY, MATCHED TO
b) REQUIRED AND SUPPLEMENTARY TOPICS.

****

THE FINAL CURRICULUM DOCUMENT FOR EACH COURSE HAS FOUR PARTS:

1) A SUMMARY CURRICULUM MATCHING SKILLS WITH TOPICS AND CONCEPTS WITH TOPICS.

2) A CURRICULUM PLAN THAT LISTS ALL THE FRAMEWORK STANDARDS MATCHED WITH THEIR RESPECTIVE SKILLS, CONCEPTS, TOPICS AND SAMPLE ASSESSMENTS.

3) THE SUMMARY CURRICULUM FOR THE COURSE OF STUDY IN THE PRECEDING YEAR, AND THE SUMMARY CURRICULUM FOR THE COURSE IN THE SUCCEEDING YEAR. (Where are your students coming from, and where are they going to?)

4) THE MASTER CONCEPT STRUCTURE AND SKILL SEQUENCE FOR THE SUBJECT AREA. (What is the larger context within which students are learning?)

TASK G: Summarize Concepts Required by the Standards

Show in a summary of the concepts required by both the K-4 and 5-8 Massachusetts 1996 Science and Technology Curriculum Framework (regular type) and by approximately 65% of the Massachusetts 1996 Mathematics Curriculum Framework for K-4 and 5-8 (italics).

Basic Concept	**Sub-concept**	**Sub-sub-concept**
Language of Science • Nature of matter • Pattern language	Entity • things, substances, waves	
	Property, *Measurement* • Observation, value, unit	Scale, Hierarchies of matter and life
		Number
		Composition
		Phase
		Temperature
		Distance, Area, Volume
		Shape
		Location, Direction
		Mass
	Change/Process	*Ratio, Percentage*
		Time, Event sequence, Rate
		Correlation, Causality
		Graph, Equation
Interdependence	Environment	
	Diversity	
	Complementarily	
Energy	Forms and transformations	Thermal, Chemical energy
		Wave energy
		Electrical energy
Waves		
Reproduction and heredity	Code (genetics)	

TASK J: Distribute Concepts to Grade Levels/Courses

The following chart shows the distribution of concepts required by the 5-8 Massachusetts 1996 Science and Technology Curriculum Framework as well as additional concepts added by the district.

Basic Concept	Sub-concept	Sub-sub-concept
Language of Science	Entity (things, substances, waves)	
	Property, Measurement	Scale, Hierarchies of matter and life
		Number
		Composition
		Phase
		Temperature
		Location, Direction
		Mass
	Change/Process	Time, Event sequence, Rate
		Correlation, Causality
Interdependence	Environment	
	Diversity	
	Complementarily	
Energy	Forms and transformations	Thermal, Chemical energy
		Wave energy
		Electrical energy
	Conservation of energy	
	Heat transfer	
Waves		
Reproduction and Heredity	Code (genetics)	
Evolution		
Motion and Forces (including Gravity)	Velocity	
	Resultant force	
Regulation		

KEY: 5th grade: _____ 6th grade: .... 7th grade: - - - - - - 8th grade: _ . . _ . _ . _ . . _

VII

3-D INSTRUCTION:

- **THE LEARNING CYCLE**
- **UNIT PLANNING**
- **INSTRUCTIONAL STRATEGIES**
- **LESSON PLANNING**

THE DIMENSIONS OF INSTRUCTION

TWO DIMENSIONAL INSTRUCTIONAL DESIGN:
When we want students to learn TOPIC INFORMATION or SKILLS the curriculum has two dimensions (2D):

CONTENT ⟷ SKILL

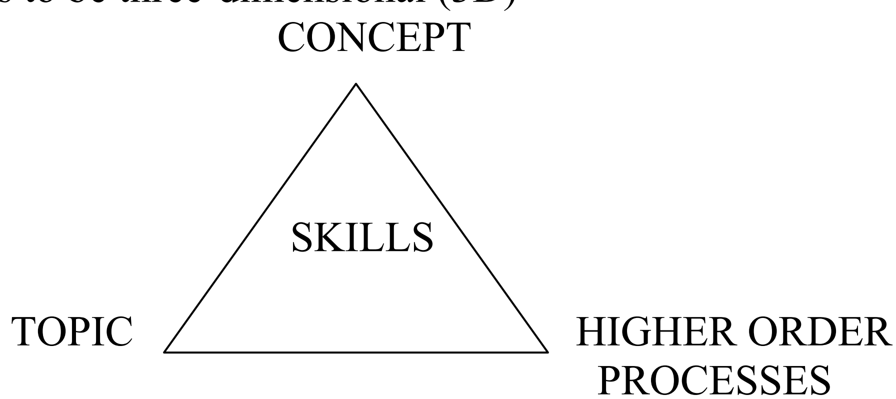
We expect students to demonstrate a high level of comprehension: they can recognize the information in unfamiliar forms; they can communicate their knowledge in their own words and in different forms of expression; they can provide their own examples; the skills have become comfortable habits.

2-D curriculum design encompasses such strategies as hands-on learning, using real-world contexts for learning skills, project and research-based instruction, etc.

MOVING FROM 2-D to 3-D:

2D → 3D : CONTENT → TOPIC / TRANSFERABLE CONCEPT

THREE DIMENSIONAL INSTRUCTIONAL DESIGN:
When we want students to TRANSFER KNOWLEDGE, applying their understanding to different and novel contexts for PROBLEM SOLVING, CRITICAL THINKING and REASONED DECISION MAKING then instruction needs to be three-dimensional (3D)



All the higher thinking processes are generated by combining generic concepts with specific topics using any number of a myriad of different skills. To teach the transfer of knowledge, students must clearly understand which knowledge it is that is transferable (i.e. the concepts), and which knowledge provides the context for its application. Then students can practice transferring knowledge using a wide variety of skills and in a wide variety of contexts.

THE LEARNING CYCLE

DEFINITION: A sequence of stages used at the unit level to organize lessons and activities focused on developing transferable skills or transferable conceptual understanding. There are many different versions of the learning cycle, some with up to five different stages. In its original and simplest form, the learning cycle consisted of just three stages for learning a new skill or concept: *formation, explanation, transfer*. This three-stage process was then enlarged by adding another stage at the beginning during which the student's engagement and interest in the new learning is gained. This first stage, the *hook,* not only attempts to prod the student's curiosity but also explores the student's already-existing knowledge of the topic.

STAGE 1: THE HOOK

The student's interests, curiosities and prior knowledge are captured. The student is ready and willing to engage in learning.

↓

STAGE 2: SKILL or CONCEPT FORMATION

The student creates a foundation understanding of the concept.

↓

STAGE 3: SKILL or CONCEPT EXPLANATION

The student's comprehension of the skill or concept is assessed

↓

STAGE 4: SKILL or CONCEPT TRANSFER

The student applies the skill or concept to a variety of questions and contexts.

The Learning Cycle is a sequence that is followed for developing transferable learning. Once the learning is gained, then a new learning becomes the focus of the next sequence of activities. The Learning Cycle is then started over for the new learning goal. The Learning Cycle can be used for both unit design, where each stage might consist of 2-6 activities, or for lesson/activity design, where each stage might influence the minute-by-minute organization of student groups, the choice of teacher vs. student centered instruction, and the number of optional activities available to students from which to choose.

STAGE 1: THE HOOK

The student's interests, curiosities and prior knowledge are captured. The student is ready and willing to engage in learning.

1. **Student motivation, interest and engagement are a major focus** at the beginning. Students are introduced to the kinds of questions and topics that can be usefully addressed. Essential questions and/or Guiding questions for the unit are introduced.
2. Demonstrations are presented of interesting, even captivating, phenomena, contexts or applications.
3. Relevance to students' personal lives, interests and backgrounds is emphasized.
4. Topics that will be investigated during Stage Two are introduced.
5. **Prior knowledge is elicited** and extended: Rudimentary skill levels or naïve conceptions are explored and de-bunked. Prior conceptual understanding is explored and organized. Students should feel comfortable that the new learning will be built upon knowledge they already have.
6. Clear connections to previous learning are established, both intellectually and graphically. Connections to future learning are also established. New concepts are connected with the overall conceptual structure (e.g. using posters, concept mapping, or categorizing questions according to concept). Students focus on how the new concept(s) is/are embedded within the larger structure of concepts.
7. The primary goal of Stage One is to hook students into the learning so that they are willing and ready to engage in the upcoming learning process.

ASSESSMENT: Students are assessed on their level of involvement and engagement in the activities, most of which require performances that have no right or wrong answers. At the least they must generate the performances on time and as requested. The level of engagement and effort evident in each will dictate the numerical grade earned.

STAGE 2: SKILL or CONCEPT FORMATION

The student creates a coherent comprehension of the concept or a facility with the skill.

- Guided questions, investigations, observations, discussions and discovery are common instructional strategies.
- **Familiar or previously learned contexts and topics are used** as clear and focused examples and illustrations, with few distractors or complications evident.
- One or two topics can be developed in tandem with conceptual comprehension or skill attainment as long as the topical information is not so complex or unfamiliar to students as to detract from learning the concept or skill.
- **Lessons and activities are chosen and sequenced to focus and emphasize particular attributes** of the concept or skill, (e.g. enduring understandings) building to a coherent comprehension or facility.
- Useful ("correct") vocabulary is introduced as efficient means of communicating new understandings.
- **Students enunciate and record the understandings** that they are to comprehend and/or the skills they are to perform. Teachers decide when and how to make knowledge explicit in a form that students may refer to and study by balancing the benefits of discovery learning with the efficiencies of presentation learning.
- Stage 3 assessments (e.g. quizzes, exit cards) that focus on particular attributes of the concept or skill are interspersed regularly as rapid feedback mechanisms.

ASSESSMENT: Student progress (e.g. on homework and class work) is regularly monitored with student effort being the primary criterion for grading (i.e. primarily formative assessment.) "Wrong" answers are as valid as "right" answers as they provide rich learning opportunities, and thus are rarely graded differently on first attempts. A good explanation or justification for a "wrong" or "different" answer often earns as high a grade as a supposedly correct answer. Particularly towards the middle and end of this Stage, Stage 3 assessments, such as quizzes or Warm-Up Questions, in which students express a correct comprehension, are included.

STAGE 3: SKILL or CONCEPT EXPLANATION

The student's comprehension of the skill or concept is assessed

- The focus of Stage 3 is assessment of student comprehension of the skill or concept. As such it often overlaps with Stage 2 in the form of quizzes assessing students' formation of correct knowledge.
- The skill or concept is explicitly recognized when embedded within familiar questions and topics.
- Appropriate vocabulary linked to the skill or concept is used.
- The skill or concept is described (what are its essential components?), and explained using vocabulary, examples, contexts, and prompts similar to those used during Stage 2.
- The skill or concept is recognized and explained in multiple modes, including text, math, graphs, oral, diagrams and illustrations, kinesthetic, etc..
- The skill is demonstrated sufficiently to achieve a task, even if not efficiently, quickly, or smoothly.
- **The student is meta-cognitive:**
  - ☐ The concept can be linked in a concept map to prior conceptual understandings. Its relationships to other concepts can be described.
  - ☐ The types of questions and circumstances for which the concept would be most useful, and for which it would NOT be useful, can be described.
  - ☐ The skill or concept can be used to describe why or when rudimentary skills or naïve conceptions occur and when they might actually be useful and appropriate.

ASSESSMENT: The focus of Stage 3 is assessment. Students express their comprehension of the concept (i.e. summative assessment). They can remember, recognize, summarize, compare and communicate what they learned in Stage 2. They link their new learning to prior knowledge and describe circumstances both in which it would be useful and in which it would not be useful. Such assessments often resemble conventional or standardized tests. The prompts are similar or close to those used during Stage 2. Often Stage 3 quizzes and targeted assessments are interspersed throughout Stage 2.

STAGE 4: SKILL or CONCEPT TRANSFER

The student applies the skill or concept to a variety of questions and contexts.

- The skill or concept is used to address new questions and previously unseen contexts and phenomena for flexible, inquiry-based problem solving and critical thinking.
- At the beginning, questions and topics are chosen that are fairly close to those used during Stage 2. Such contexts become progressively less familiar, less transparent, and more complex.
- A variety of thinking processes (application, analysis, synthesis, evaluation) are used for combining concept(s) and topics. Several such processes are usually evident in a particular learning activity.
- Students take increasing responsibility for the choice of question or topic and which skills are necessary to carry out the learning activity.
- Some topics and skills are mandated for all students.

ASSESSMENT: Students are assessed on the degree to which they are able to transfer the skill or concept during problem solving and critical thinking. The degree of transfer-ability is indicated by the novelty of the context or topic in question, the choice of skill or concept as the vehicle(s) for learning, the variety of skills and processes that can be successfully used, and the accuracy, breadth, insight and creativity of the resulting product or performance. Such assessment is often termed "authentic assessment" since knowledge transfer is emblematic of many, if not most, real-life problem solving. Also characteristic of authentic assessment, there is little difference between the learning activities and the assessments; the assessment is often just the last learning activity.

DISCUSSION QUESTIONS:

1. Which of the four stages do you think would take the greatest amount of student time? Explain. Try to attribute relative, or proportional, time durations to the stages that might be typical for a particular type of unit.

2. Which stage(s) could, in some circumstances with some students, be truncated or shortened with little ultimate affect on student skill learning? On student conceptual understanding?

3. The learning cycle was introduced as applying at the unit level of instructional planning. How useful would the learning cycle be for planning and conducting individual lessons?

TASK: CHARACTERIZE YOUR TWO LESSONS ACCORDING TO YOUR OWN LEARNING CYCLE

Turn your attention back to the two lessons that you brought to this workshop. You have now become familiar with the stages of the learning cycle and have developed a learning cycle design that you are comfortable with.

At which stage within the learning cycle would each of your lessons best fit? Explain your decisions. You may prefer to answer this question either by considering your lessons in their original forms or as you might prefer to modify them.

LESSON ONE:
Title: ______________________________

Placement within the learning cycle: ______________________
Explanation:

LESSON TWO:
Title: ______________________________

Placement within the learning cycle: ______________________
Explanation:

CHARACTERIZING LESSONS

You were asked to bring to the workshop two of your "favorite" lessons, whatever they might happen to be. You might have brought lesson plans or the student assignment sheets, text, readings, or other lesson-related materials. This task asks you to characterize each lesson according to the indicated criteria. Your characterizations should describe the explicit learning goal of the lessons more than aspects that it reinforces or depends upon: "What does this lesson intend students to learn?" "What should students understand, know, and be able to do at the end of the lesson that they did/could not at the beginning?"

DIRECTIONS:

1. Briefly title and describe each lesson (so that you may refer to this document some months from now and quickly remember what it is about.)

2. Without consulting the other people in your group, characterize the lesson according to the criteria given in the chart.
   A. If you feel that the lesson is 3-D, then concentrate on identifying the concept(s) and topic(s) rather than higher-order thinking processes.
   B. Use the "Percentage (%) Emphasis" column if you feel it necessary to indicate a weak/strong, dominant/background balance.
   C. NOTE: If you are not familiar with the learning cycle stages, then leave this part of the chart blank.

3. Describe your lesson to the other people in your group without telling them your choices for characterizing it. Facilitate a group discussion around your lesson focused on characterizing it. You may wish to take notes of this discussion to help you later with improving the lesson.

4. Compare your own, first-thought characterizations with those of the group.

LESSON ONE:
Title: ____
Brief description: ____________________________________

	My first thoughts	Group consensus	% **Emphasis**
Concept, if any, this lesson teaches			
Topic, if any, this lesson teaches			
Skill, if any, this lesson teaches (List skills only; not hi-order processes)			
Is this lesson 1-D, 2-D, or 3-D ?			
Is this lesson one concept-many topics, or one topic-many concepts ?			
In which stage of the learning cycle would this lesson best fit?			

LESSON TWO:
Title: ____
Brief description: ____________________________________

	My first thoughts	Group consensus	% **Emphasis**
Concept, if any, this lesson teaches			
Topic, if any, this lesson teaches			
Skill, if any, this lesson teaches (List skills only; not hi-order processes)			
Is this lesson 1-D, 2-D, or 3-D ?			
Is this lesson one concept-many topics, or one topic-many concepts ?			
In which stage of the learning cycle would this lesson best fit?			

WHAT DID YOU LEARN FROM CHARACTERIZING THESE LESSONS?

Why were you asked not to worry about identifying specific higher-order thought processes for the lessons that you felt were 3-D ?

How did characterizing these lessons help you understand their role or effectiveness in student learning?

How would you change these lessons in light of the characterizations you just carried out?

CONCEPT-BASED UNIT PLAN DEVELOPMENT

TASK:

In consideration of your particular teaching situation and needs, check the boxes next to the actions in each of the six steps that are most relevant and useful for you that you would include in planning a unit. You may add steps of your own that are not listed under "Other."

1. **Familiarize yourself with the definition of the concept: What is the transferable learning that students are to gain at the end of the unit?**
   - ❑ Locate the concept within the greater, master conceptual structure. Notice its relative position to other concepts.
   - ❑ Investigate what prior conceptual understandings students might be bringing to their study of this unit. Use the master conceptual structure to see how such prior learning connects to the concept.
   - ❑ Study the generalizations, text definition, and/or concept map for the concept. If necessary, create your own generalizations that will guide student learning and assessment.
   - ❑ Other:

2. **Familiarize yourself with the state objectives that you will have students learn through the concept.**
   - ❑ Considering these mandated standards and your grade level, which of the concept generalizations should be emphasized?
   - ❑ Which objectives will be included in each of the three stages of the learning cycle?
   - ❑ Can you summarize and organize the mandated standards into a list of required topics?
   - ❑ Other:

3. **Establish learning cycle Stage 3 and (end of) Stage 4 assessments.**

   Stage 3:
   - ❑ What are the basic facts, vocabulary, and skills that you want students to know and do as a result of this unit and that they will need as they practice transferring the concept?
   - ❑ What format of assessment will you use to evaluate student comprehension of the basic facts, vocabulary, and skills?
   - ❑ How will students organize and express the essential components and vocabulary of the concept, topic information and skills?
   - ❑ Other:

   End of Stage 4:
   - ❑ Will you use a common performance assessment at the end of Stage 4 for all students? Or will you have different students choose different performances, even though they might all be judged according to the same standards?
   - ❑ When in the learning cycle will you communicate these expectations to students?
   - ❑ To what degree will you involve students in establishing expectations and levels of performance?
   - ❑ Other:

4. **Develop a Stage 2 sequence of activities or lessons.**
   - What mandated standards are to be incorporated into Stage 2?
   - What lessons and activities do you have presently available that could be used?
   - What lessons or activities could be used or created that would focus student learning on particular generalizations with a minimum of distraction? Since the purpose of these lessons and activities is to develop understanding of the concept, they would ideally begin with familiar or simple contexts and topics.
   - How are the lessons and activities related to each other in order to create a meshed, progressive sequence of learning culminating in an explicit comprehension?
   - What special needs must you plan for ; What special interests could you cater to?
   - How, If, and When will students obtain text, generalizations, and/or concept map definitions of the concept?
   - Other:

5. **Develop a Stage 1 hook.**
   - What introductory activity (either to be created or taken from available resources) might engage students' interest?
   - When and how will you relate the new learning within the larger conceptual structure and their prior conceptual learning?
   - How will you check for prior knowledge of the concept and/or topical information in the unit?
   - Other:

6. **Develop a Stage 3 sequence of activities or lessons.**
   - What lessons or activities could be used to help students review, summarize or organize their comprehension of the concept in preparation for the Stage 3 assessment?
   - What lessons or activities could be used to help students remember the topical information and skills that were learned during Stage 2?
   - Other:

7. **Develop Stage 4 activities and lessons.**
   - What mandated standards are to be incorporated into Stage 3?
   - What lessons and activities do you have presently available that could be used, and which must you create?
   - Which activities or lessons at the beginning Stage 4 will create a smooth transition from Stage 2 activities and lessons?
   - What range of activities and lessons might challenge all students?
   - What special needs must you plan for, What special interests could you cater to?
   - Other:

UNIT PLAN TEMPLATE

(Spacing is intended for electronic use of this template. Alternately, attach additional paper as needed.)

UNIT TITLE: ______________________________ SUBJECT/COURSE: ___________________________

GRADE LEVEL:_______ PERFORMANCE LEVEL(S): ___________________________

TOTAL UNIT DURATION (Number of periods x Length of period(s)): ___________________________

SPECIAL EQUIPMENT, SUPPLIES, OR RESOURCES NEEDED :

PRE-REQUISITE KNOWLEDGE :

A) Concept: ____

B) Topic: ____

C) Skill: ____

TARGET LEARNING OUTCOMES (CURRICULUM)

Specify the learning outcomes for the unit in at least one of the following categories: concept, topic/context, and skill. You may leave one or even two blank, with the understanding that the combination of the categories in the lesson planning affects the type and level of learning generated. Use your course curriculum document for guidance.

I. TRANSFERABLE CONCEPT(S): What do you want students to **understand**?

TRANSFERABLE CONCEPT(S) (include generalizations)	**ASSOCIATED STATE FRAMEWORK STANDARDS** (include complete text, even if repeated from below)

II. TOPIC, CONTEXT, INFORMATION, TEXT TITLE/GENRE, CONVENTIONS: What do you want students to **know**?

TOPIC, CONTEXT (include details as necessary)	**ASSOCIATED STATE FRAMEWORK STANDARDS** (include complete text, even if repeated fro above or below)

III. BASIC SKILLS, PROCEDURES, PROTOCOLS: What do you want students to learn to **do** to what level of accomplishment? (Communication, Physical/Kinesthetic action [e.g. measuring, writing, mapping], following scripted/repeated procedure or algorithm)

I: Introduction **R:** Reinforcement **M:** Mastery

SKILL (I, R, M) (include generalizations)	**ASSOCIATED STATE FRAMEWORK STANDARDS** (include complete text, even if repeated from above)

ASSESSMENT

1) **PRE-ASSESSMENT: (Part of Stage 1 of Learning Cycle)**
   At the beginning of the unit/lesson, how will you determine what students already understand/know/do related to the intended learning outcomes? (Attach copies of student assignment sheets and/or hand-outs)

2) **COMPREHENSION/FLUENCY ASSESSMENT: (Stage 3 of Learning Cycle)**
   After students have formed the targeted skill(s), concept(s), or topical information, How will you measure their command of vocabulary, their degree of comprehension, their ability to compare/contrast, and/or their fluency in the performance of skills in different conditions or contexts? (Include copies of tests and student assignment sheets for performances or products. Also include rubrics and/or scoring guides for each.)

Unit planning starts here →

3) **FINAL (POST-) ASSESSMENT of STUDENT ABILITY TO TRANSFER KNOWLEDGE: (End of Stage 4 of Learning Cycle)**
   What student performance(s) will demonstrate that students understand and/or can do the targeted concepts and/or skills in a variety of contexts/topics? How will you measure different degrees of transfer-ability? (Include copies of tests and student assignment sheets for performances or products. Also include rubrics and/or scoring guides for each.)

4) **STUDENT SELF-ASSESSMENT(S): (Could be at any or all stages of the learning cycle)**
   How and when will students reflect on their own learning and progress?

SYLLABUS

STAGE ONE - ENGAGEMENT, HOOK:

LESSON TITLE – DURATION	DESCRIPTION		
	Learning Outcomes (Essential Question(s) Concept-Topic-Skill, Generalizations)	Instructional Strategies and Student Grouping	Resources

STAGE TWO - CONCEPT/SKILL FORMATION:

LESSON TITLE - DURATION	DESCRIPTION		
	Learning Outcomes (Essential Question(s), Concept-Topic-Skill, Generalizations,)	**Instructional Strategies and Student Grouping**	**Resources**

STAGE THREE - CONCEPT/SKILL EXPLANATION:

LESSON TITLE - DURATION	DESCRIPTION		
	Learning Outcomes (Essential Question(s), Concept-Topic-Skill, Generalizations)	Instructional Strategies and Student Grouping	Resources
ASSESSMENT:			
ASSESSMENT:			
ASSESSMENT:			

STAGE FOUR - CONCEPT/SKILL TRANSFER:

LESSON TITLE - DURATION	DESCRIPTION		
	Learning Outcomes (Essential Questions, Concept-Topic-Skill, Generalizations)	**Instructional Strategies and Student Grouping**	**Resources**
ASSESSMENT:			
ASSESSMENT:			
ASSESSMENT:			

UNIT PLAN TEMPLATE

(Spacing is intended for electronic use of this template. Alternately, attach additional paper as needed.)

TITLE: THERMAL ENERGY AND HEAT TRANSFER IN COASTAL ECOSYSTEMS

SUBJECT AREA: SCIENCE GRADE LEVEL: 9/10 COURSE NAME: ENVIRONMENTAL SCIENCE

DURATION: 3-4 wks

SPECIAL EQUIPMENT, SUPPLIES, OR RESOURCES NEEDED : None

PRE-REQUISITE KNOWLEDGE (DYRSD A1):

A) Concept: Temperature.
Energy Transformation

B) Topic: Earth within the solar system;

C) Skill: CBL probeware

TARGET LEARNING OUTCOMES (CURRICULUM) (A2, B1, B3)

Specify the learning outcomes for the unit in at least one of the following categories, concept, topic/context, and skill. You may leave one or even two blank, with the understanding that the combination of the categories in the lesson planning affects the type and level of learning generated. Use your concept, skill and/or knowledge master structures for guidance.

I TRANSFERABLE CONCEPT(S): What do you want students to **understand**?

TRANSFERABLE CONCEPT(S) (include defining generalizations)	**ASSOCIATED STATE FRAMEWORK STANDARDS** (include complete text), **DY LOCAL CURRICULUM OBJECTIVES**
Heat Transfer	

HEAT TRANSFER 1. Thermal energy (heat) always moves from high to low temperature entities, and once such a flow begins it will continue until the high and low temperature entities are at the same temperature, at which time the flow of thermal energy stops. 2. Since fast-moving molecules colliding with neighboring slow-moving neighbors will cause them to speed up, thermal energy will move (i.e. conduct) between molecules that are in contact, eventually traveling by collision-to-collision from regions of high temperature (i.e. high molecular motion) to regions of low temperature (i.e. low molecular motion) until there is no difference in temperature and molecular motion. 3. Since an increase in temperature and molecular motion causes almost any substance to expand, regions of a fluid that are heated to a higher temperature than others will have lower densities than the comparable cooler regions, and as long as the two regions of the fluid are connected in some way (and as long as gravity is acting), they will tend to circulate, with the hot region rising and the cooler region falling. 4. The thermal energy of an object readily and continuously converts into the wave energy of electromagnetic radiation, which travels in straight lines to be readily absorbed by some nearby object or substance and converted back into the thermal energy of the new object, with all objects and substances in the universe continuously emitting and absorbing radiation, converting back and forth to thermal energy. 5. Even though the processes of thermal energy flow from one entity to another are conveniently categorized as happening either through contact	DY LOCAL OBJECTIVE 1: "Explain the difference between radiation, conduction, and convection as methods of heat transfer within and between substances." ***MASSACHUSETTS CURRICULUM STANDARDS:*** *Core and Integrated Standards:* EAR1.5: Explain how the transfer of energy through radiation, conduction, and convection contributes to global atmospheric processes, e.g. storms, winds. (Core and Integrated stnd.) EAR1.8: Explain how the revolution of the earth and the inclination of the axis of the earth cause the earth's seasonal variations (equinoxes and solstices). (Core and Integrated stnd) *Core Standards:* EAR1.7**: Provide examples of how the unequal heating of the earth** and the Coriolis Effect **influence global circulation patterns and their impact on Massachusetts weather and climate, e.g. convection cells, trade winds, westerlies, polar easterlies, land/sea breezes, mountain/valley breezes.** (Core stnd) TEC4.1: Differentiate among conduction, convection, and radiation in a thermal system, e.g., heating and cooling a house, cooking. (Core stnd) TEC4.2: Give examples of how conduction, convection, and radiation are used in the selection of materials, e.g., home and vehicle thermostat designs, circuit breakers. (Core stnd) TEC4.4: Explain how environmental conditions influence heating and cooling of buildings and automobiles. (Core stnd) *Optional Standards:* EAR1.6: Explain how the layers of the atmosphere affect the dispersal of incoming radiation through reflection, absorption, and re-radiation. EAR1.9: Describe how the inclination of the incoming solar radiation can impact the amount

(conduction), through the large-scale movement of a fluid (convection), or through radiation emission and absorption (radiation), in the majority of real-world situations all three processes occur at the same time, albeit one or two often predominating over the other, and affect each other's changes.	of energy received by a given surface area. TEC4.5: Identify and explain the tools, controls, and properties of materials used in a thermal system, e.g. thermostats, R Values, thermal conductivity, temperature sensors.

II. TOPIC, CONTEXT, INFORMATION, TEXT TITLE/GENRE, CONVENTIONS: What do you want students to **know**?

TOPIC, CONTEXT	ASSOCIATED STATE FRAMEWORK STANDARDS (include complete text)
Atmospheric processes, such as winds, storms, formation of and motion of air masses. The causes of the seasons. The regions of the electromagnetic spectrum. **Unit Vocabulary:** At the conclusion of this unit the student should be able to use the following vocabulary in the correct context of the unit: conduction, convection convective flow heat land breeze radiation (radiant enery) sea breeze temperature	EAR1.5: Explain how the transfer of energy through radiation, conduction, and convection contributes to global atmospheric processes, e.g. storms, winds. (Core and Integrated stnd.) EAR1.8: Explain how the revolution of the earth and the inclination of the axis of the earth cause the earth's seasonal variations (equinoxes and solstices). (Core and Integrated stnd) *Core Standards:* EAR1.7**: Provide examples of how the unequal heating of the earth** and the Coriolis Effect **influence global circulation patterns and their impact on Massachusetts weather and climate, e.g. convection cells, trade winds, westerlies, polar easterlies, land/sea breezes, mountain/valley breezes.** (Core stnd)

III. BASIC SKILLS, PROCEDURES, PROTOCOLS: What do you want students to learn to **do**? (Communication, Physical/Kinesthetic action [e.g. measuring, writing, mapping], scripted/repeated procedure, rote use of algorithm)

SKILL	ASSOCIATED STATE FRAMEWORK STANDARDS (include complete text)

Use of CBL probeware, including temperature probe and graphing calculator. Calorimetry procedures for measuring specific heats, latent heats, and heats of vaporization.	

ASSESSMENT

1) PRE-ASSESSMENT:

At the beginning of the unit/lesson, how will you determine what students already understand/know/do related to the intended learning outcomes? (Attach copies of student assignment sheets and/or hand-outs)

Students will work in cooperative groups to assemble a list of statements describing everything they know about the subject heat, temperature and how heat moves from place to place. Groups will then each create five questions about their natural and everyday environment that would be best answered with knowledge of heat. Groups will create posters for each task and share out to the whole class. A common poster for each task inclusive of all the input from the class groups will be assembled and displayed.

2) COMPREHENSION/FLUENCY ASSESSMENT: (Stage 3 of Learning Cycle)

After students have formed the targeted skill(s), concept(s), or topical information, How will you measure their command of vocabulary, their degree of comprehension, their ability to compare/contrast, and/or their fluency in the performance of skills in different conditions or contexts? (Include copies of tests and student assignment sheets for performances or products. Also include rubrics and/or scoring guides for each.)

Students will be given a short-answer, multiple-choice and mastery assessment of the vocabulary and factual information associated with the unit (see list under TOPIC/CONTEXT description above.) Many of the questions will use the same contexts and examples as were used during the Stage Two development of the concepts. They will also demonstrate mastery of the lab procedure and skills involved in measuring specific heats, latent heats, and heats of vaporization of both solids and liquids.

3) FINAL (POST-) ASSESSMENT of STUDENT ABILITY TO TRANSFER KNOWLEDGE: (End of Stage 4 of Learning Cycle)

What student performance(s) will demonstrate that students understand and/or can do the targeted concepts and/or skills in a variety of contexts/topics? How will you measure different degrees of transfer-ability? (Include copies of tests and student assignment sheets for performances or products. Also include rubrics and/or scoring guides for each.)

Students will be asked to choose one question from the life sciences, one from the physical, and a third from the earth sciences and respond to the questions using as many of the thermal energy and heat transfer concepts as possible and suitable. Students may choose the method of investigation and presentation, but they must arrange for at least an audience of 5, one being the teacher.

4) **STUDENT SELF-ASSESSMENT:**
How will students reflect on their own learning and progress?

As part of the COMPREHENSION/FLUENCY ASSESSMENT, students will be asked to reflect on what they felt they had learned the best, and which areas they were least confident of. They will also be asked to suggest three questions concerning subjects of interest to them that pertain to heat and heat flow, and they will asked about their level of commitment to investigating those questions.

UNIT SYLLABUS

UNIT NAME: THERMAL ENERGY AND HEAT TRANSFER IN COASTAL ECOSYSTEMS

UNIT STRATEGY FOR LEARNING DESCRIBED IN TERMS OF LEARNING CYCLE STAGES, 2-D & 3-D MODES.

NOTE:

2-D: BASIC SKILL + TOPIC/CONTEXT = COMPREHENSION: COMPARE/CONSTRAST FLUENT SKILL APPLICATION

3-D: CONCEPT + SKILL + TOPIC/CONTEXT = KNOWLEDGE TRANSFER: PROBLEM SOLVING AND CRITICAL THINKING

This unit begins with a Stage Two overview of the major generalizations associated with Temperature, Thermal Energy, and Heat Transfer. A series of hands-on activities using a discovery inquiry approach focus on the difference between temperature and thermal energy (heat) and its modeling at the molecular level. Students are lead to express the major generalizations. Students are asked to learn the vocabulary and re-express the generalizations in other forms. The choice of metabolism and sand-water-air as topical contexts was meant to facilitate connections with coastal ecosystems at a larger scale. Students go through two more activities, on heats of fusion and vaporization, and the other on heat transfer. Students then break into groups, each responsible for investigating and presenting on one of the four methods of heat transfer (radiation, conduction, convection, evaporation). With so much conceptual ground to cover, this Stage Two will take 3+ weeks (at one period a day). It is primarily a discovery review that is 3-D – students are carrying out hands-on activities to first learn the dimensions and understandings of the concepts and to do so in the context of coastal ecosystems as much as possible.

Stage Three consists of a short quiz closely associated with the activities that ensures that all students have a minimum prior conceptual foundation before moving on to practicing concept transfer. Students will spend a total of three class periods reviewing and testing out.

Stage Four is highly 3-D: It consists of several different options from which students can choose. All students could be required to be part of a cooperative group that addresses in depth one question about a coastal ecosystem. A common rubric for conceptual transfer is used with minor variations across the various activities. Students are asked to submit for summative evaluation their best performance that illustrates transfer-able knowledge of the concepts as well as topical applications to coastal ecosystems.

SYLLABUS

STAGE ONE - ENGAGEMENT, HOOK:

LESSON TITLE – DURATION	DESCRIPTION		
	Learning Outcomes (Concept-Topic-Skill, Generalizations, Essential Questions)	**Instructional Strategies**	**Resources**
Burning hand – 20 min	Hook: Heat transfer can be deceiving. Why doesn't my hand burn?	Put alcohol on palm of hand and light it. Student groups with white boards: Why doesn't hand burn? HMWK: List of 5 facts and 2 questions about heat and heat transfer.	
Know about it? 45 min (1 period)	Establish prior knowledge bases of students.	Students work in cooperative groups to create a poster collection of what everyone already knows, and another poster of their questions. Groups then share out. Student facilitator then captures group responses to create common lists for the class and display them.	
Question choice 1 period	Establish a rubric for how the responses to the questions for Stage 4 will be assessed.	Students create a "new" list of 3 questions, one from life, earth, and physical science, beginning with their original two and including changes taken from all the questions discussed and posted the previous day. In their cooperative groups, they then create a series of suggested criteria for assessing a final project addressing 3 questions.	

STAGE TWO - CONCEPT/SKILL FORMATION:

<table>
<tr><th rowspan="2">LESSON TITLE - DURATION</th><th colspan="3">DESCRIPTION</th></tr>
<tr><th>Learning Outcomes (Concept-Topic-Skill, Generalizations, Essential Questions)</th><th>Instructional Strategies</th><th>Resources</th></tr>
<tr><td>Metabolism lab
2-3 periods</td><td>ESSENTIAL QUESTION:
How can the sensation of hot or cold be so different for different individuals and even organisms in the same circumstances, or for the same individual in different circumstances?</td><td>Students are responsible for generating their own lab reports, starting from scratch, even though they are working in 2+2 cooperative groupings.

Students investigate their own metabolic rates with a focus on the energy transformation of chemical to thermal energy. Students exercise to increase their pulse/metabolic rates, and record their sensations of temperature.

Students touch various surfaces around the classroom, from metal air louvers to jackets to flooring to paper, and record their sensations of "temperature." They then use thermometers to measure the actual temperatures.

Students discuss why an organism would run a fever during sickness, and how maintaining a constant internal temperature affects the transformation of stored or consumed chemical energy to the thermal energy of the organism.</td><td></td></tr>
</table>

LESSON TITLE - DURATION	DESCRIPTION Learning Outcomes (Concept-Topic-Skill, Generalizations, Essential Questions)	 Instructional Strategies	 Resources
Metabolism lab – cont.		Students contrast the warm-blooded and cold-blooded patterns of metabolism, the category to which many of the organisms, including micro-organisms, important to a coastal ecosystem belong.	
Lab: Specific heats of sand, water, air. 3 periods	How do the temperatures through the seasons of a coastal ecosystem's sand/ground, water, and surrounding air affect the generation of bio-matter within the ecosystem? by react so differently to the flow of thermal energy Because the unique molecules that make up every different bulk substance have unique masses, sizes, shapes, and charges, including charge distributions, and are uniquely related to their neighbors in terms of orientation, separation distances, and bonding strengths and patterns both within each molecule and between neighboring molecules in all the different phases of matter, the bulk-	1. Use the CBLs and the heat sensors to determine the difference in heating or cooling of a sample of sand, water, and air. This can be used to teach or reinforce the use of computer spreadsheets and graphs to manage data while writing a lab report on the activity.	

Lab: Heats of fusion & vaporization 2 periods	Because the unique molecules that make up every different bulk substance have unique masses, sizes, shapes, and charges, including charge distributions, and are uniquely related to their neighbors in terms of orientation, separation distances, and bonding strengths and patterns both within each molecule and between neighboring molecules in all the different phases of matter, the bulk-scale properties of freezing and boiling temperatures, heat capacities, and heats of fusion and vaporization each reflect in some way the molecular-scale variations.	Students use moth balls (naphthalene) to map a heat of fusion graph, and measure the heat of vaporization of water. Students discuss the large flows of thermal energy involved in the formation of different forms of precipitation as well as from evaporation in coastal ecosystems. They discuss the extent and role of evaporative cooling in ecosystems as well as everyday events. Student also discuss the feedback effects that such flows might have on various meteorological events.	

Lab – Heat Transfer overview 2-3 period		Students see heat transfer at a large scale of having four on-going processes happening simultaneously: conduction, convection, and radiation, as well as evaporation/condensation. Students investigate and compare two methods of popping popcorn: using a pan over a flame, and using a microwave. Their comparisons are taken from the perspective of heat transfer: which methods were prevalent to which extent and at which approximate rates? In the course of the lab, students are provided with readings on each of the four processes.	
Lab – Conduction 1 period	These labs would each be conducted by a different group of students, who would prepare a class presentation to the remaining 2/.3's. Total time: 3 period	Students use a multi-metal star-wheel to measure the different conductivities of different metals.	
Lab – Convection 1 period		Students design a convection cell for maximum AND MINIMUM velocity in a 250ml beaker.	
Lab – Radiation 1 period		Students investigate the technology and underlying science, at the molecular scale, for how a microwave oven heats substances, and why it reacts typically to metal components.	

STAGE THREE - CONCEPT/SKILL EXPLANATION:

LESSON TITLE - DURATION	DESCRIPTION		
	Learning Outcomes (Concept-Topic-Skill, Generalizations, Essential Questions)	**Instructional Strategies**	**Resources**
Review and assess. 3 periods		A short quiz closely associated with the activities ensures that all students have a minimum prior conceptual foundation before moving on to practicing transfer. The vocabulary list is tested here, and is the description of coastal ecosystems from the perspectives of temperature, thermal energy, and heat flow.	
ASSESSMENT:			
ASSESSMENT:			
ASSESSMENT:			

STAGE FOUR - CONCEPT/SKILL TRANSFER:

<table>
<tr><th rowspan="2">LESSON TITLE - DURATION</th><th colspan="3">DESCRIPTION</th></tr>
<tr><th>Learning Outcomes (Concept-Topic-Skill, Generalizations, Essential Questions)</th><th>Instructional Strategies</th><th>Resources</th></tr>
<tr><td>Friction lab
2-3 periods</td><td>Essential question: How can the process of friction change things or substances?

Generalizations:

THERMAL ENERGY, CHEMICAL ENERGY
All energy transformations involving objects or substances include at least some flow of energy to and/or from their molecules, resulting at the bulk level in changes in temperature, phase (either or both together called changes in thermal energy) and/or composition (called changes in chemical energy).

Whereas the temperature of a bulk thing or substance is defined as the average amount of motion of its molecules, its thermal energy measures the total amount of molecular motion.</td><td>Students are responsible for generating their own lab reports, starting from scratch, even though they are working in 2+2 cooperative groupings.

Students experiment with four different activities that highlight friction: kneading clay, rubbing toothbrushes together, tapping a thumbtack with a small hammer, stretching a rubber band quickly. They take before and after temperature measurements.

Students discuss in their groups the meaning of the temperature measurement versus the concept of total thermal energy produced as preparation for writing part of the conclusion.

At beginning of second period, teacher begins with 15 min demonstration of trying to start fire with friction, using various folklore approaches. Students consider the possibility that friction could also generate a phase change and a change in composition.</td><td></td></tr>
</table>

	The flow of energy into or out of objects or substances can affect their molecules in any combination of three ways: the kinetic energy of the molecules can change, resulting in a temperature change at the bulk scale; the pattern of molecular motion, described as some combination of vibration and translation, can change, resulting in a phase change at the bulk scale; or the bonds between and among the atoms within the molecules can change, resulting in a change in composition at the bulk scale**.**	HMWK: Students are asked to web research or read material on how heat shields on space capsules and the space shuttle dissipate heat from friction through temperature change, phase change, and composition change.	
Ecosystem Research Project option: 4 Student periods	Apply the concepts of temperature, thermal and chemical energies and their transformations, as well as the concept of heat transfer, to some question focused on the biological productivity or diversity of a coastal ecosystem.	Students may form a working cooperative group with an end-goal of a presentation to an audience of at least 4 other students who must be quizzed at the end on their learning.	
		Essential Question: Why is it that a hydrogen fire couldn't burn you unless you were practically be consumed by it, whereas a hydrocarbon fire can cause critical burns at quite a distance?	

		Essential Question: How does using the dishwasher affect the temperature and humidity of my house in both summer and winter, and how should I use it (open it right away? Let it cool before opening?) to help my overall utility bills>?	
		Essential Question: How do the different boiling temperatures of ethanol, water, acetone, and vegetable oil affect their evaporative cooling?	
ASSESSMENT:			
ASSESSMENT:			
ASSESSMENT:			

LESSON PLAN TEMPLATE

(Spacing is intended for electronic use of this template. Alternately, attach additional paper as needed.)

TITLE: ______________________________

SUBJECT AREA: ______________ GRADE LEVEL: ___ COURSE NAME: ______________

DURATION: ______________ UNIT OF STUDY: ______________________

STAGE OF LEARNING CYCLE (circle one):

hook	concept/skill formation	concept/skill expression	concept/skill transfer

BRIEF SUMMARY: (2-3 sentences describing major content, activities, expected results)

REQUIRED INSTRUCTIONAL RESOURCES:

<u>TARGETED LEARNING OUTCOMES (CURRICULUM)</u>

Specify the learning outcomes for the lesson:

1) TRANSFERABLE CONCEPT(S), GENERALIZATIONS. What do you want students to **understand**?

2) TOPIC, CONTEXT, INFORMATION, TEXT TITLE/GENRE, CONVENTIONS: What do you want students to **know**?

3) BASIC SKILLS, PROCEDURES, PROTOCOLS: What do you want students to **do**? (Communication, Physical/Kinesthetic action [e.g. measuring, writing, mapping], scripted/repeated procedure, rote use of algorithm)

ASSESSMENT

ON-GOING ASSESSMENT: During and/or at the end of the lesson, what strategies will you use to monitor student learning progress? (Note: "*On-going*" refers to how each lesson fits within the unit plan that includes pre- and final assessments.)

INSTRUCTION

List a numbered sequence of activities, assignments or learning activities. Provide enough detail so a teacher teaching the lesson for the first time could follow the plan.

□ Include time durations for different phases and activities.
□ Include student grouping format/structure for each lesson segment.
□ Include a *Do-Now*. (A short activity at the beginning of the class intended to transition students to the learning mode, re-connect with the on-going flow of lessons, and orient them to the anticipated learning.)
□ Indicate where and when on-going assessment strategies will occur.
□ Attach referenced student assignment sheets and/or handouts, resource lists, etc..
□ Specify probable homework with scoring guide and/or rubric(s). (Actual homework often differs from the planned homework since lessons often change depending on student reactions.)
□ **For hook lesson(s):** Include an advance organizer introduction that connects the intended learning for the unit to prior learning as mapped within the master concept, skill, or topic structures.

	ACTIVITY, TASK, ASSIGNMENT	STUDENT GROUPING	TIME
1	DO-NOW/WARM-UP:		
2			
3			

ALL LEARNING BEGINS WITH A QUESTION

Literacy: **Problem Solving, Critical Thinking & Considered Decision Making** **that is** **Flexible** **and** **Inquiry-Based.**	*Students can transfer previously learned knowledge to new **questions**. They can answer, address, or investigate **questions** in a creative, insightful, fruitful, and/or enjoyable way, and they can effectively communicate this process to others.* *Students can address a wide variety of **questions**, including **questions** that they have not previously considered or **questions** in unfamiliar contexts.* *Students motivate and orchestrate their own problem solving and critical thinking. They develop their own **questions**, design and carry out procedures appropriate for the **question**, modify the **question** and procedure as they progress, and use newly acquired knowledge as a basis for further inquiry around a newly formed **question**.*

Essential Questions: Questions about a particular context, topic, or situation whose response requires students to use the skill or concept(s) that are the intended learning outcomes of the unit or lesson. Essential questions cannot be answered with Yes/No or simple, factual responses. Neither are they so all-encompassing as to be vacuous or aimless.

Essential Questions Connect The Curriculum To Instruction.

Learning Cycle	How Essential Questions Facilitate the Learning Cycle
Stage One	A well-chosen question is often an excellent hook for student interest and engagement. The question may be "big" enough to spawn many associated questions for individual lessons, particularly during Stage Two.
Stage Two	One or more questions shared by all students can both facilitate the skill/concept formation and have them learn information about an important topic.
Stage Three	Tests and performances of comprehension often focus on questions such as those addressed during Stage Two. Often students are responsible for answering any "hook" question from Stage One.
Stage Four	The ultimate goal is for students to pose their own questions. Even though this stage may begin with one or more essential questions addressed by all students, often cooperative groups of students will each choose and address separate questions.

CREATING ESSENTIAL QUESTIONS

An essential question asks students to combine a skill or concept with a particular topic or context. An essential question focuses on a particular context, topic, or situation whose response requires students to use the skill or concept(s) that are the intended learning outcomes of the unit or lesson.

Essential questions:

- cannot be answered with Yes/No or simple, factual responses.
- are not so all-encompassing as to be vacuous or aimless.
- can be used at almost any scale: as a 10-minute warm-up or reflection/application, as the focus of a single lesson or as an organizer for an entire unit.

Essential questions are often an excellent vehicle for, and often even require, detailed or extensive background knowledge of the context or situation. Background and contextual knowledge acquired through an essential question that is well focused conceptually is generally learned rapidly and remembered for months and years (i.e. rapid and long-term retention).

Essential questions provide an instructional template that taps into a fundamental insight of education: all deep, conceptual learning begins with a question. Transferable concepts are associated with questions, while topics and contexts are associated with facts and information.

Examples:

QUESTION	CONCEPT	TOPIC
What is the difference between bread and toast?	Property, Composition	Bread
Why can't we drink salt water?	Concentration	Cellular osmosis; hyper/hypotonic solutions
Why can't mixed recycled plastics be melted together to make new plastic products?	Structure, Phase (solidity)	Polymers
Why are large predators so rare?	Interdependence	Wildlife
Why are large predator <u>species</u> so rare?	Selection (natural)	Wildlife
Why is the Earth divided into different layers?	Property – Patterns in composition and density	Geology; the Earth's structure
Why does a solution of ground up spinach glow red?	Energy transformation or Waves: Reflection, Absorption, Transmission, Emission	Cell organelles; Photosynthesis
Why do you have to fast or not drink before some blood tests and not others? Why does the fast have to last so long?	Composition	Blood and food
What is the relationship between volcanoes and earthquakes?	Location	Volcanoes and Earthquakes
How alive are viruses?	Process (Life is defined by processes; what they <u>do</u>, not what they <u>are</u>)	Biology

QUESTION	CONCEPT	TOPIC
What would happen if … ? … penguins didn't have black backs and white bellies? … mosquitoes disappeared forever? … the ice caps melted totally?	A generic prompt for questions focused on interdependence	Interactions in the natural environment
Why do soap bubbles burst?	Fluid pressure; Kinetic theory of matter.	Soap bubbles
Why are tree rings made up of different layers with different colors?	Growth and development; Composition	Trees
How is the number of bacteria in a colony related to the temperature of their environment?	Correlation; Growth and Development	Bacteria; Health
Why do different household cleaners work on different kinds of stains and dirt?	Chemical reaction	Household products
Why would a strong anti-acne drug such as Accutane (isotretinoin) that strongly affects the skin cause severe birth defects?	Growth & Development: Differentiation	Fetal development
Why are smell, taste, and color, almost half our senses, dedicated to sensing just one property: composition?	Interdependence	The senses
If you were filling a water bed and forgot to turn off the hose, would it burst?	Pressure	Household
Why does the water at a beach first recede when a tsunami approaches?	Wave (properties)	natural disasters
How do schools of fish and flocks of birds coordinate their movements so quickly?	Regulation/Control	Animal behavior
How do fish perceive which direction is "up" ?	Resultant force	Fish
How can astronomers learn so much about stars and planets when they only have the light from them to get information?	Waves	Astronomy
What color(s) would you paint the (solid) walls and floors of a greenhouse to maximize plant growth?	Wave absorption, reflection; Color	Horticulture
How are the properties and processes of tree xylum and kidney tissues similar and different?	Process: osmosis, diffusion	Anatomy & Physiology; Plants
Is it true that a dead person's hair and fingernails continue to grow?	Growth and Development	Anatomy & Physiology
What would happen if you painted an exterior surface with latex paint in freezing temperatures?	Chemical kinetics	Home trades

QUESTION	CONCEPT	TOPIC
How can rock particles be carried along continuously by a fast-moving stream?	Pressure (Bernoulli's Principle)	Erosion
How does an oil burner burn oil?	Chemical reaction	home trades
Why is plastic sewer pipe in a house so much noisier than cast iron pipe?	Wave production, absorption, propagation	home trades
When you freeze an egg, why does it always crack end-to-end on one side?	Resultant force	Everyday events
Why do the natural sugars in corn start to turn to starch as soon as the corn is picked? How does the corn plant keep the natural sugars from turning to starch while it is living?	Regulation/Control	Agriculture
Why do places around the world that are physically and climatically so similar have such different plants and animals?	Evolution: Speciation	Contrasting ecosystems
Could a predator ever hunt its prey to extinction?	Carrying capacity/Limits	Any particular ecosystem
How does a fog-free mirror work?	Reflection	Everyday objects
Why did the old CRT computer monitors and TV's collect so much dust, while the new flat-screen monitors don't?	Electricity & Magnetism (attraction/repulsion, electrostatics)	Everyday objects
NOT VERY GOOD ONES		
Can something be living and not alive? (Recommended by Heidi Hayes Jacobs at Coventry workshop 1-20-09)		

TASKS:

1. For each of the questions above,
   a. discuss in your group what an appropriate duration and format for learning activity(ies) might be.
   b. discuss and list background or contextual information that might accompany the associated learning activity.

2. Ask a question about a topic:
   - ☐ The Earth's Layers, or The Solar System
   - ☐ The Skeleton, or Spiders
   - ☐ The Oceans, or Weather
   - ☐ Rockets, or Batteries

   That requires the use of one of these concepts:
   - ☐ Energy Transformation
   - ☐ Form and Function
   - ☐ Composition
   - ☐ Rate

3. Choose a concept and topic combination that would be appropriate for a class you are now or have recently taught and create one or more essential questions.

CONCEPT	TOPIC	QUESTION

CONSTRUCTING CONCEPT MAPS

INSTRUCTIONS –

1. Choose the concept that is to be the subject of the map. (e.g. PROPERTY, ENTITY, FORM-AND-FUNCTION). It is usually one word and at most is several words). Write this term as the first entry in a list.

2. Then continue the list by identifying the associated concepts and topics associated with the concept.

3. Rank order the list of associated terms from the most general, inclusive, and important ones to the most specific, detailed ones that might even be examples. It is often easiest to use a simple three-way system of "1 – 2 – 3" or "most – medium – least." The ranking can be approximate; you will have lots of opportunity to modify it later.

4. Use the Inspirations Software to construct a preliminary concept map. First create a rectangular box for your key concept that is the subject of the map. Place this box at the top center of the page.

5. Create a rectangular box for each of the associated terms on your list from Step #2. Place this on the page according to their rank order: the most general ones go directly under the subject concept, the terms with a medium ranking go in the middle part of the page, and the lowest ranked terms go towards the bottom of the page.

6. Place terms (in their boxes) close to other terms, either with the same ranking or above or below them, that seem to be closely related to each other.

7. Now for the hard part: Use the linking tool in Inspirations to create connections among the concepts. This step is difficult because the line linking two (or more) concepts must be labeled with words or phrases. These words must create sensible statements when read from the top box down to the bottom box. The statements summarize and explain the subject concept as well as the relationships among all its associated terms. Each boxed term can have many links starting or ending with it.

8. Concept maps are generally read from top to bottom. However, put an arrowhead on each link to show which direction it should be read. In general, the more links you generate the better the map because it then contains more information. Start with links going vertically, then add links that cross from side-to-side or that go from bottom to top. Links can snake around and through the map, and eventually you will learn to use Inspirations to link several terms together in a chain.

9. While you are generating links among the boxed terms you will probably want to move the boxes around, even changing their ranking up and down. Try to produce a map where as few links as possible cross over each other so that each link is easy to read.

SOME GUIDELINES ON CREATING CONCEPT MAPS

BUBBLES:

1. You may only use a "bubble term" once – you may not repeat bubbles.
2. You may ONLY use rectangular or oval bubbles – no fancy graphics. Choose one shape and then use it throughout.
3. A concept map is organized vertically: concepts that are most general and wide-ranging go at the top, while more specialized and detailed ideas go towards the bottom. Organize your concepts into "layers."
4. Examples do not go in bubbles. They are listed at the end of a line with no box around them.
5. After organizing the bubbles into layers, move them left or right so that the connectors are least tangled.

CONNECTORS:

1. Connecting lines that run down the page do not have arrow heads.
2. Connecting lines that are read up or sideways on the page have arrow heads.
3. The words in the bubbles and the words on the connecting lines must together read as a coherent statement.
4. Start with links going vertically, then add links that cross from side-to-side or that go from bottom to top. Links can snake around and through the map, and eventually you will learn to use Inspirations to link several terms together in a chain.

COLORS:

Generally use a single color for your bubbles. However, you may occasionally find that your map is much more readable if you color-code bubbles in certain sections of your map. If you use color, you must include a key that defines the meaning of the different colors.
Use a white background.

GRADING RUBRIC:

	POINTS		X'-PLIER	weighted points
	possible	earned		
All concepts are included and bubbled, and only concepts are bubbled (examples and connecting words/phrases are not bubbled). Each concept is only included once.	10			
Concept ideas are organized on the page from the most general at the top to the most specific at the bottom, with concepts of equal import at the same level. Concepts that naturally group into themes or subjects are grouped together and color coded.	10			
All connector lines include linking phrases. Concept ideas are connected with phrases that create accurate and reasonable statements. The linking words demonstrate a deep understanding of the relationship between the ideas.	10			
The statements incorporated into the map summarize all of the major knowledge learned so far and explain the relationships among the concepts	10			
The map is integrated and coherent, rather than a collection of isolated "little maps." Many of the concept ideas have multiple connectors. The map is branched and tree-like, rather than string-y. A significant number of connectors run sideways and upwards.	10			
The map is organized so that it reads easily and is graphically attractive. Connecting lines that run from top-to-bottom do not include arrow heads, while those that run sideways or bottom-up do. There are no misspellings or grammatical errors in the statements created by the bubbled concepts and the linking phrases.	5			
The connector lines are visually easy to follow, including curved lines with link phrases strategically located and sized for easy reading. Their layout includes devices such as branching points (link phrases that branch to more than one concept) and "bouncing" connectors that create statements that span more than one concept.	5			
TOTAL POINTS				

RATIONALE FOR COOPERATIVE LEARNING

Cooperative learning is one more powerful instructional strategy for facilitating student learning. The rationale for including it in your teaching repertoire stresses both academic and social learning for students:

1. Group sharing and processing of subject-area content allows students to:
   - practice recalling what has just been learned
   - express new learning in their own words and ways
   - fill in one another's knowledge gaps
   - share other students' relevant experiences and associations
   - experience discussion that may stretch students beyond recall and comprehension

2. Higher-order thinking is socially mediated. The mental processing required to transfer new knowledge to new situations requires expression, response, and re-expression. Mature thinkers internalize this social interaction as a "silent conversation" with oneself.

3. Frequent but short (2-3 minutes every 5-10 minutes) group or pair sharing in a lesson is a deterrent to daydreaming and increases student participation and attentiveness by providing changes in pace and format. Adolescents' natural tendency to socialize and interact with each other is harnessed rather than being a frequent source of behavior problems. The inevitable 10-20% of any group process that is off-task provides a "safety valve" for students to deal with the small friction points between them (pencils dropping, books overlapping, etc.)

4. Students are stretched socially by cooperative projects where there is a division of labor (i.e. task specialization), shared goals that foster group interdependence, and some form of individual accountability for each group member. Group members must learn to lead, follow, and compromise for the group to succeed. When students are grouped heterogeneously (e.g. by ability or gender), they may develop an appreciation for students outside their of their peer group and gain an understanding of other perspectives as they strive to "get along" in a new, task-oriented group.

5. Cooperative group learning is motivating! Whether it be a simple structure such as "turn to your neighbor and discuss for 30 seconds what the word _______ means" or a complex multimedia presentation culminating a unit of study, most everyone has more fun working with others than alone.

THE FUNDAMENTAL FORMULA FOR COOPERATIVE LEARNING

There is a difference between group or shared work and cooperative learning. The fundamental equation for cooperative learning is:

STRUCTURE + CONTENT + PRODUCT = CO-OPERATIVE LEARNING

SOME POSSIBLE COOPERATIVE GROUP STRUCTURES

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SEVEN POSSIBLE STRUCTURES

There are numerous cooperative learning structures. The following seven represent a selection from simple to complex.

1. Pair and Share	2. Group Discussion	3. Heads Together	4. Interview
5. Round Table	6. Cooperative Projects	7. Jigsaw	

DIFFERENTIATING INSTRUCTION

The basis of differentiated instruction is accommodation to student strengths, needs and proclivities. A great deal of training is devoted to balancing the at times overwhelming number of differences among your students with the very finite amount of time you have to design, search for or prepare materials.

When implementing a 3-D curriculum that has a clear concept and a topic, then it is possible to keep a strong backbone that holds together the different activities or tasks being carried out by students. The backbone consists of the concept and its defining generalizations.

the concept becomes common to all students.	**The topic can accommodate** student interests and backgrounds. A variety topics within a classroom is ideal for practicing transfer of the concept.
	The skills can accommodate. The skills that students incorporate into their performance or product can accommodate their strengths or be a focus for improvement.
	The depth of conceptual understanding can be accommodated to students by assigning more, less, or different generalizations for the same concept to focus their learning.
Students can share their performances or products through the common conceptual framework, while appreciating, even challenging, each other's applications.	
The focus of assessment is on the student's ability to combine the concept with the chosen topic – the generalizations for the concept provide a clear standard for measuring the student's transfer–ability rather than communication skills.	

DIFFERENTIATED INSTRUCTION - EDUCATION FOR ALL

****

Education for all means **ACCOMMODATION TO DIFFERENCES.**

What are the characteristics of the educational program that can be modified?

I **CURRICULUM**

A. **CONCEPTS.** Concepts differ according to their

i) ________________ ii) ________________ iii) ____________________

B. **TOPICS.** Topics differ according to their

____

____

C. **SKILLS/PROCESSES.** The cognitive skills and higher thinking process skills differ according to their:

____

____

II **INSTRUCTION**

A. **ACTIVITY FORMAT.** Lessons can involve students in different behaviors such as: (focus on what the individual student is doing)

____

____

B. **GROUPING SIZE AND RELATIONSHIP.** Students can be grouped to work cooperatively in different numbers. Groups can cooperate in different ways, such as:

____

____

C. **TIME DURATION.** Lessons or activities can take different periods of time.

III **ASSESSMENT**

A. **FORMATIVE OR SUMMATIVE.** Formative assessment provides feed-back to students and input to teachers with a minimum of judgment. Formative assessment is usually on-going and woven into the classroom flux. Summative assessment is delineated and results in a judgment of the learning.

B. **ASSESSMENT FORMAT.** Can vary from multiple choice to portfolio.

C. **TIME DURATION.** Can take different periods of time.

QUESTION:

WHAT ARE THE DIFFERENT CHARACTERISTICS OF **STUDENTS and TEACHERS** TO WHICH THE EDUCATIONAL PROGRAM MUST ACCOMMODATE?

STUDENTS differ according to their:

____

____

____

TEACHERS differ according to their:

____

____

____

****

How does **ACCOMMODATION LINK TO THESE DIFFERENCES?**

CONCEPT accommodates to ______________________________

____

____

TOPIC accommodates to ______________________________

____

____

SKILL/PROCESS: ______________________________________

____

____

ACTIVITY FORMAT: ____________________________________

____

GROUPING SIZE & RELATIONSHIP:____________________________

____

TIME DURATION: ______________________________________

POSSIBLE INSTRUCTIONAL STRATEGIES

The following categories were used for describing teacher instructional strategies over the course of classroom observations done as part of a research study on conceptual change*. The researchers noted in their conclusions that the below strategies proved more powerful in combination than in isolation. "Conceptual change teaching should probably be thought of as a coherent approach to teaching rather than as a collection of individually useful strategies."

QUESTIONING:
Choice
Explanation
Probe
Misconception
Student question
Non-conceptual change:
- Open-ended questions
- Memory questions

TEACHER PRESENTATION:
Advance Organizer
Emphasis
Relate
Teacher explanation
Everyday example/illustration

STUDENT TASKS:
Choice
Explanation
Misconception (articulated by student)
Contrast
Everyday example/illustration
Discrepant
Non-conceptual change:
- Open-ended task
- Memory task

SOURCES:
Emphasis
Relate
Summary
Contrast
Explanation
Everyday example/illustration
Discrepant event

**Teaching Strategies Associated with Conceptual Change Learning in Science*, Smith, Edward L., Blakesless, Theron D., Anderson, Charles W., 1993, JRST, Vol. 30, No. 2, pp. 111 – 126.

The following categories of "Interactive Engagement Methods" were used in another research study* that was looking at the effectiveness of conceptually explicit instructional materials. (They are listed in descending order of popularity with teachers, with the caveat that the effectiveness of each strategy might well not correlate with its popularity among teachers.)

Collaborative Peer Instruction

Microcomputer-based Labs

Concept Tests

Modeling (As in "*Modeling Instruction in Physics*")

Active learning Problem Sets or Overview Case Studies

Physics education research-based text (Modeling Physics), or no text

Socratic Dialogue Inducing Labs

* Hake, R. 2002. Lessons from the physics education reform effort. Conservation Ecology, 5(2): 28 [online] URL: http://www.consecol.org/vol5/iss2/art28

TEACHING STRATEGIES*

New forms of student assessment ask for new ways of instruction in the classroom. Exemplary teachers model effective assessment strategies in their teaching and, ultimately, this assists improvement in learning. Strategies listed by Gabel (1995) that describe good instruction:

1. **Wait time:** Pausing for an extended period of time after asking a question in the classroom results in an increase in achievement.
2. **Learning Cycle Approach:** Using the learning cycle approach (exploration, invention, application) results in better content achievement, improved thinking skills, and more positive attitudes toward science.
3. **Cooperative Learning:** Using cooperative learning for classroom and laboratory learning increases student achievement, attitudes, and on-task behavior.
4. **Analogies:** Using analogies in the teaching of science results in the development of conceptual understanding by enabling the learner to compare similarities of something familiar to something unfamiliar.
5. **Concept Mapping:** Using student-generated and teacher-generated concept maps for teaching science concepts results in improved student achievement and more positive student attitudes.
6. **Microcomputer-Based Laboratories:** Using computers to collect and display data from science experiments enables students at the secondary level to understand science concepts and learn to use science process skills.
7. **Computer Simulations:** Using computer simulations to represent real world situations enables students to become more reflective problem solvers and to increase their conceptual understanding.

8. **Systematic Approaches in Problem Solving:** Planning the solution of mathematical chemistry and physics problems in a systematic way enables students to solve the problems correctly more frequently.
9. **Conceptual Understanding in Problem Solving:** Understanding concepts qualitatively enables students to solve quantitative problems in physics and chemistry more effectively.
10. **Science-Technology-Society:** Using a Science-Technology-Society approach in the teaching of science results in an increase in the number of students taking additional science courses and advanced level courses, as well as changing students' attitudes toward science and their understanding about the nature of science and its relationship to technology and societal issues.
11. **Discrepant Events:** Using discrepant events in science instruction results in cognitive conflict that enhances students' conceptual understanding.
12. **Real-Life Situations:** Using real life situations in science instruction through the use of technology (films, videotapes, videodisks, CD-ROMS) or through actual observation increase student interest in science, problem solving skills, and achievement.

* Taken from: Voss, Burton E. *Alternative Assessment in K-12 Science Education.* URL: www.enc.org/reform/journals.

Gabel, D. (Ed.) (1994). *Handbook of research on science teaching and learning.* New York: MacMillan.

The Brain-Based Education movement, particularly popular in the late 1990's, largely addressed instructional strategies, many of them derived from research on how students best learn skills or information. The four primary recommendations of the "Brain-Based" movement for improving instruction are:

1. **Repetition**, in conjunction with
2. **Time distribution** of practice. Repetition should be spaced at least overnight.
3. **Feedback**, provided as soon after the performance as possible.
4. Use of **graphic organizers**.

The fifth recommendation largely addresses curriculum:

5. **Internal logic and coherence** of the materials.

Sousa, David A. (1995). *How the brain learns*. Reston, Virginia: National Association of Secondary School Principals.

VIII

3-D ASSESSMENT

• TWO STAGES OF ASSESSMENT

• ASSESSING CONCEPTUAL TRANSFER

FORMATIVE ASSESSMENT – WHAT IS IT?

All the various strategies of classroom formative assessment share **four common characteristics:**

1. The teacher assesses classroom behaviors and competencies by **direct observation.** The teacher makes note of the frequency of a response (can spell a particular word; can identify a theme sentence; can establish a cause-and-effect relationship), the pattern of prompts that elicit the response and/or the context in which the response occurs, the time between a prompt and the response, the degree of connectivity of the response to related concepts and of contextual information.

2. The student's behavior and competencies are **observed frequently**, on the order of several times per hour, and over a period of time, often on-going. For diagnostic purposes, formative assessment might stretch over several days or even weeks, with focused observation and data gathering episodes occurring a couple times a week.

3. Student progress is **measured against specific performance standards** (criterion-referenced assessment) rather than being compared against other students or some norm. Students' progress is often also measured as the measured change in particular behaviors or competencies and the rate or time over which the change occurred.

4. Using the on-going observations of how prompts, contexts and student performances are related, the teacher **adjusts the learning activities**, often on a daily or even minute-by-minute scale, in order to improve student learning, thus regulating and controlling the teaching-learning process.

SUMMATIVE ASSESSMENTS WITHIN CONCEPT-BASED UNITS

MAJOR CHANGE: Within every concept-based unit there are **two** major summative assessments.

1. **The first assessment evaluates students' comprehension of the concept.** Such assessments often resemble conventional or standardized tests.

   - ☐ Do students know the associated vocabulary?
   - ☐ Can they remember, recognize, summarize, compare and communicate the generalizations that define the concept?
   - ☐ Can they link the generalizations to previously learned concepts?
   - ☐ Can they apply the concept generalizations to topics and prompts similar to those encountered while learning the concept?
   - ☐ Can they describe circumstances both in which the concept would be useful and in which it would not be useful?

2. **The second assessment evaluates transfer-ability.** These assessments are authentic: they are generally indistinguishable from preceding transfer learning activities that use real-world applications, contexts, and problems. Such assessments occur at the end of Stage 4 of the learning cycle in which students practice transferring the concept, and are often merely the last activity in which students engage.

   - ☐ To what degree are students able to transfer the concept during problem solving and critical thinking?
   - ☐ How novel to the student is the context or topic in question?
   - ☐ How extensive is the variety of skill(s) used for transfer and for communicating?
   - ☐ What is the degree of accuracy, breadth, insight and creativity of the student's product or performance?
   - ☐ To what degree does the product or performance have value beyond success in school?

AN OPPORTUNITY FOR DIFFERENTIATION

All students within a differentiated classroom are required at a minimum to reach the comprehension level of concept knowledge. Some students may require the entire time allocated to the unit to reach this stage. In other words, they may spend the vast majority of time in Stage 2 (Comprehension) of the learning cycle, with perhaps some "near" transfer applications towards the end. Often such students have joined a concept-based class mid-stream, and much of the additional time spent in Stage 2 is dedicated to back-loading comprehension of concepts previously learned in the class but not by the student in question.

On the other extreme, some students may test out of comprehension (i.e. complete the Stage 3 comprehension assessment) and dedicate most of their time to problem solving and critical-thinking learning activities requiring them to transfer their conceptual knowledge. In other words, they spend the majority of their time in Stage 4 of the learning cycle.

THE TWO LEVELS of ASSESSMENT for CONCEPT UNDERSTANDING or SKILL ATTAINMENT

ASSESSMENT FOR COMPREHENSION OR FLUENCY:
The purpose of this level of assessment is to ensure that students have a firm grasp of the terminology associated with the skill or concept as well as a functional comfort with using its elements. In other words, students must first become familiar with the capabilities and limitations of their new learning and develop an ease of use, even if with a fairly few exemplars chosen for their few distractors, before being asked to transfer the skill or concept.

With this level of assessment, the concept or skill is understood "explicitly." Students will often have an implicit, or intuitive grasp of a skill or concept without being aware of how or what they are doing or thinking. Thus the comprehension level of assessment is a very important step towards students being aware of their own thinking – the important meta-cognitive realm. At some future time when they are strategizing how to solve a complex problem, much of the vocabulary they will use will be what is required for this level of assessment. The student can describe in her own words the component elements of either the skill or concept and how they are related to each other using correct terminology. For skill attainment, the student can demonstrate the skill within contexts, resources and constraints closely related to those in which she learned it.

As the first plateau of conceptual understanding, comprehension of the concept means that the student uses it correctly as a vocabulary term within contexts or topics similar to those in which she learned it. The student can describe, in her own words, the concept's essential component understandings in terms of generalizations, and give illustrations of each generalization similar to those studied while learning the concept. The student also uses the generalizations to explain the connections among the concept being learned and previously learned concepts. The student can recognize and illustrate the concept in different representations, such as charts, graphs, maps or graphic organizers.

Assessments for comprehension often resemble what many teachers might be familiar with as a traditional end-of-chapter test, with multiple choice or short-answer questions, many of which might have clear answers.

ASSESSMENT FOR TRANSFER:
The goal of this level of assessment is higher-order critical thinking and problem solving as understood to be a student performance that combines one or more skills or concepts with particular contexts or topics. With the focus on transfer-ability, the variety and novelty of the contexts and topics within which the student uses the skill or concept to effectively respond to a question are important parameters. With conceptual transfer, different skills can be emphasized or chosen as the method by which the student somehow combines the concept with the context or topic in question. Thus the student's ability to transfer a skill can be embedded within an assessment for concept transfer.

Assessments of transfer-ability are authentic in that they focus on real-life situations and questions that are generally fairly complex and rich in contextual detail. The student is usually required to create an appropriate problem-solving strategy. Furthermore, the assessment differs little if at all from the precursor learning activities – often the assessment is merely the last in a string of "practice" activities.

TWO DIMENSIONS FOR ASSESSING SKILL OR CONCEPTUAL UNDERSTANDING

INCREASING SKILL AND PROCESS DIFFICULTY

Creativity

Evaluation

Synthesis

Analysis

Application

Bloom's Taxonomy **of thinking processes.** Organized by increasing complexity

TRANSFER

Assessments usually combine two or more of the higher-order thinking processes into a coherent, orchestrated performance in which the individual processes are subsumed under a comprehensive task or activity focused on transfer-ability. The individual processes are difficult to segregate into dedicated tasks or activities. The distinctions among them are useful to educators for judging the difficulty of tasks or activities, but are so fine-grained as to be a source of confusion and distraction for students if used overtly as a rubric or instructional criterion.

Simple every-day objects & events

Familiar situations and contexts

INCREASINGLY COMPLEX AND DISTANT TOPICS FROM STUDENT'S FAMILIAR CONTEXTS
(ascertained by teacher's judgment)

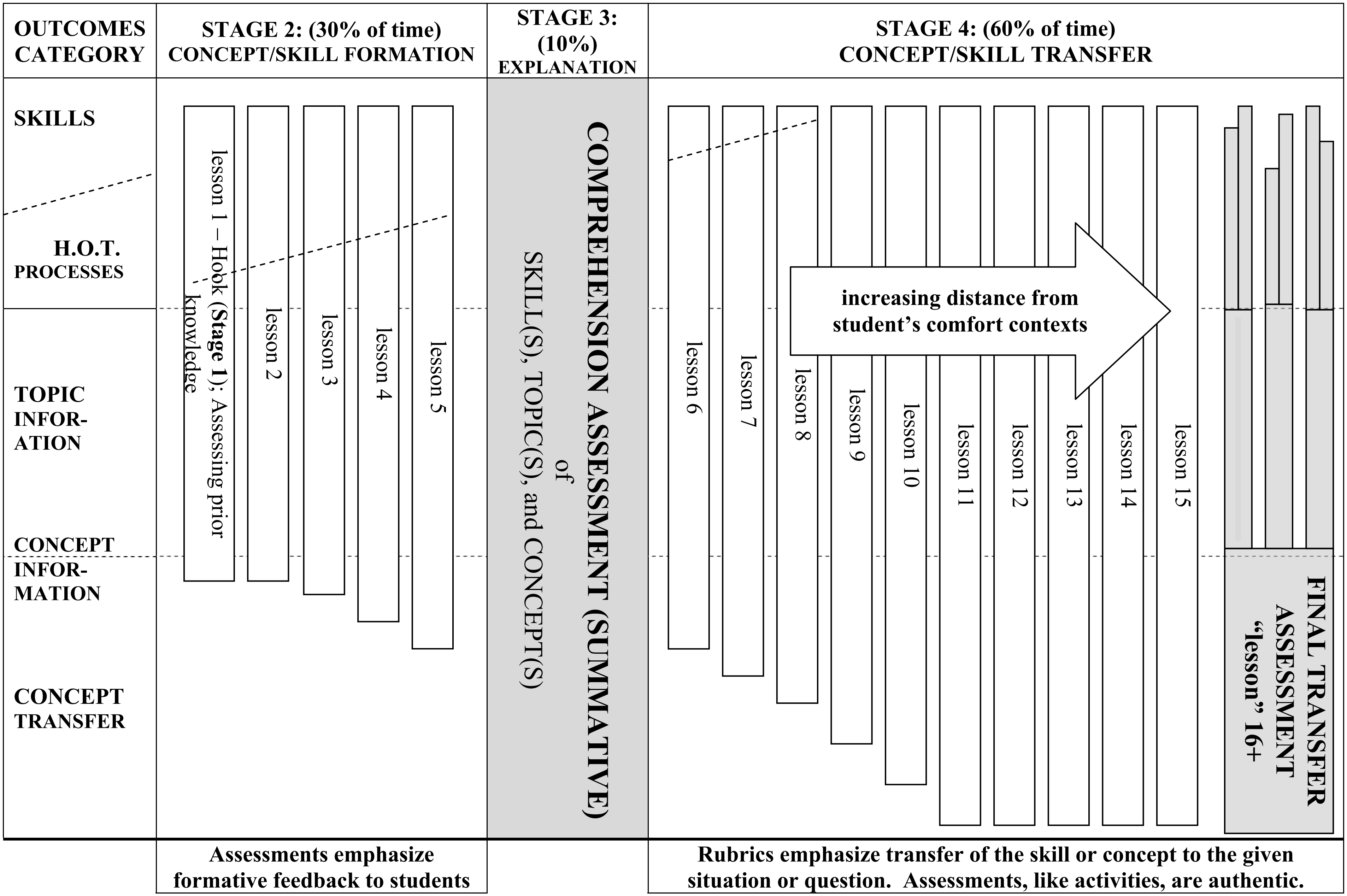
COMPREHENSION

Students remember, recognize, summarize, compare and communicate. Assessments resemble conventional or standardized tests. Prompts are similar to those used during learning.

Comprehension

Memory

HOW ASSESSMENTS MESH WITH THE LEARNING CYCLE



DESIGNING A STAGE 3 UNIT ASSESSMENT
COMMON TO ALL CLASSES

I PURPOSE

A. The focus of the Stage 3 common unit assessment is student comprehension; students express their comprehension of the concept or skill (i.e. summative assessment).
B. Another major function of the assessment is feedback to the teachers: to generate specific recommendations on whether and how the curriculum and/or instruction should be changed to improve student learning the next time the unit is taught.

II BEGIN WITH THE CURRICULUM

A. Connect each item in the assessment to a generalization, a topic, a skill, or some combination of the three.
B. Read the generalization, topic description, or skill. Create items for each, or for combinations thereof. Consider whether the student's response to the item could be back-mapped to specifically identifying what the student did nor did not learn.
C. Include "Teacher Choice" topics.

III. FOCUS ON COMPREHENSION, BUT CHECK FOR TRANSFER

A. To what degree can students remember, recognize, summarize, compare, and communicate what they learned in Stage 2? Do they know the important vocabulary, facts, and information (given in the curriculum)? Can they describe how their new learning links to prior knowledge, both from previous units and from their personal experience? Can they describe circumstances both in which their new knowledge would be useful, and in which it would not be useful?
B. Use prompts and contexts similar to those used during Stage 2 learning.
C. Check for budding transfer with prompts that ask for near and even far transfer.

IV. INCLUDE DIFFERENCES IN STUDENT LEVELS AND TEACHER CHOICES

A. Design a comprehensive, inclusive assessment that reaches to the top expectations, challenging some students to stretch and reach.
B. Include items that test for different "Teacher Choice" topics.
C. Distinguish among levels and teachers' choices with the scoring guide and rubrics

V. USE DIFFERENT ITEM GENRES AND FORMATS

A. Use item genres familiar from conventional tests: multiple choice; short answer; constructed response; etc.
B. Choose item genres that balance the grading and scoring requirements with valid and reliable assessment.
C. Use a variety of genres for the multiple items associated with each learning outcome.

VI. COMBINE COMMON SCORING WITH EXTRA CREDIT FOR UNFAMILIAR ITEMS

A. Use rubrics for complex responses; scoring guides for objective responses.
B. Use a common set of rubrics and scoring guides for all teachers.
C. Some items are extra credit for some students and/or some classes.
D. Some items, such as those associated with Teacher Choices, will assess comprehension for some students and transfer for others, and they are written with such a dual purpose in mind.

VII. FOLLOW A DESIGN PROCEDURE

Remember: Unit design begins with the Stage 3 comprehension assessment.

1. Create a draft assessment working with as many teachers as possible: Sketch it out; Rough it in. Flesh it out as much as necessary for the “vision” of student performance to have body and shape. If the unit has been taught in the past then the draft might be close to the final version; if not, then the draft might have shape and body, but not be detailed or filled in before moving on to the design Stages 1 and 2.
2. If the draft still needs substantial work to be transformed into the final assessment then carry it out while teaching Stages 1 and 2. All teachers contribute ideas for both content and genres. One or two teachers are coordinators who assemble, edit, and communicate the final version as soon as possible within Stage 2.
3. Delineate the main body of the assessment that will be common to all students, regardless of level of teacher, and agree to a common grading guide and rubrics. Identify the remaining items as either comprehension for the classes or students who covered the material or transfer for those students who did not. Agree to a common scoring guide or rubric.

VIII COLLECT AND SHARE DATA FROM THE ASSESSMENT

A. Using the common scoring guide and/or rubrics for the common section of the assessment, collect data on average grade and spread of grades (how many students at each quartile?).
B. Identify items on which students performed particularly well and particularly poorly. Collect data on the extent and severity of each performance pattern.
C. By comparing student performance of items associated with the same learning outcome identify particular gaps or strengths in student learning.
D. Each teacher identify six representative student tests: two at the high end, two at the low end, and two middle performances.
E. Teachers meet to compare the data from their classes and compare the representative tests. The meeting results in written recommendations on how to improve the curriculum, instruction, and assessment the next time the unit is taught.

GENERIC RUBRIC FOR ASSESSING CONCEPTUAL UNDERSTANDING

This generic rubric is designed to measure a student's understanding of a particular transferable concept. The evaluator of the assessment needs to be familiar with the definition of the concept. This generic rubric would be the basis for developing a more focused rubric for a particular concept.

This generic rubric measures degrees of conceptual understanding in terms of the student's ability to transfer a concept to different contexts and questions for the purposes of problem solving, critical thinking and reasoned decision making. The rubric assumes that each concept has been explicitly defined in terms of multiple generalizations (enduring understandings) and that the assessment instrument would be keyed to the generalizations chosen and listed in the curriculum documents. The rubric may be used for diagnostic, formative, or summative assessments.

This rubric is focused on the single-concept scale because the concept is the minimum intellectual "quantum" that can reasonable provide a basis for substantial literacy. Individual concepts are also the minimum scale at which units are designed in the instructional plans. A unit with a multi-concept structure would ideally use a separate rubric for each of the concepts, since a student's ability to transfer conceptual knowledge depends on a student's familiarity with both the concept and the contexts, both of which can differ from concept to concept for any one person.

Each of the below descriptions is assumed to be inclusive of the previous level's performance indicators and exclusive of the indicators above it. The rubric is designed to produce scores that are decimals. For example, a score of 2.5, or 3.2.

The rubric is ostensibly built on a 0 - 5 scale, but the 5th level (creative understanding) is one that rarely appears on school goals or expectations. Thus this generic rubric was intended to be treated primarily as a 0 - 4 scale with Advanced Transferable Understanding as the top level. The 5th level could serve as a basis for identifying and assessing advanced or gifted and talented students.

LEVEL OF UNDERSTANDING	PERFORMANCE INDICATORS
0: Below or Minimal Measurement	• No response. • Does not recognize the term. • Can give a first-order generalization, example or simple question utilizing specific information and contexts, when prompted with the name of the concept and salient details of the context.
1: Formative Understanding	• Can recognize the name and synonyms of the concept. • Can give at least one instance or example of its application that had previously and recently been explicitly learned. • Can give at least one question, even if previously considered, that could be usefully addressed by the concept. • Can enunciate a generalization focused on the concept. The level of the generalization (1st to 3rd) can be used as a fine-grain measurement. So a first order generalization would actually be a –0- rating as described above. • Cannot spontaneously transfer the knowledge to a previously un-studied topic or context, even when the specifics and vocabulary of that subject or context are familiar. • Cannot effectively use the concept to carry out a directed inquiry investigation or design task.

LEVEL OF UNDERSTANDING	PERFORMANCE INDICATORS
2: Explicit Understanding; Comprehension	• Can name the concept and its various synonyms and give multiple instances and applications that had been previously and recently learned. If first given a familiar instance or application that had been previously studied, then can name the concept, using the most appropriate synonym for the specific context. • Can express higher order generalizations focused on the concept and then illustrate each generalization within simple everyday objects or events or a familiar topic or context. The student includes the essential, most important generalizations, but not necessarily all. • Can relate and interweave two or more higher order generalizations for the concept, describing how they relate to and complement each other and explaining instances and applications that are best addressed by a combination of the generalizations. • Can give several questions within two or more different contexts that could most usefully be addressed by the concept, even if the questions are close to ones previously considered. The questions are focused on the concept even if they are drawn from simple, everyday objects or events or situations and contexts familiar to the student. • Can use and translate among non-literal statements such as similes, metaphors, mathematical expression, graphs, charts, or maps to explain and recognize the concept. The meaning's accuracy is preserved in the translation. • Can summarize and paraphrase the concept's meaning, perhaps reordering or re-arranging its elements while preserving its meaning. • Cannot spontaneously transfer the knowledge to a previously unstudied topic or context, even when the specifics and vocabulary of that subject or context are familiar. • Can use the concept in a directed inquiry investigation or design task, but still cannot incorporate the knowledge of the concept into the creation of a self-directed investigation or design project.

LEVEL OF UNDERSTANDING	PERFORMANCE INDICATORS
3: Proficient Transferable Understanding	• Can create or identify multiple questions and applications not previously considered that are clearly addressed by the concept and that are drawn from a variety of contexts and topics that are familiar. Students may need extended time to generate the questions. • In describing applications of the concept, can choose from among its component generalizations the one or two that are most relevant and productive for addressing the question. • In describing applications of the concept, can identify and describe a context's elements, events, and relationships relevant to a question within the framework of the chosen generalization(s). • In describing applications of the concept, establishes the relative organization and importance of the elements, events, and relationships. • Can apply the knowledge of the concept to a previously unstudied question, topic or context, even when the specifics and vocabulary of the subject or context are unfamiliar. However, the skills and processes used to carry out the application are familiar and comfortable. The degree of this ability can be measured at a finer grain by the degree of novelty of the topic or context to which the conceptual knowledge is being transferred. • Can apply the knowledge of the concept to a familiar question, topic or context while using complex and challenging skills (graphs, charts, speech, writing, etc.) in a strategic and purposeful manner.

LEVEL OF UNDERSTANDING	PERFORMANCE INDICATORS
4: Advanced Transferable Understanding	• Can create or identify multiple examples of questions or applications not previously considered that are fruitfully if not obviously addressed by the concept within a wide variety of contexts, many of which are not familiar beyond the context clues available from a problem prompt or associated research. • Can use skills, even some that are novel or unpracticed, to combine the concept with a topic or context to address a question in a facile, clear manner, communicating with a voice effectively directed at a designated audience. • Can create or identify examples of questions or applications for which the concept is only one of several possible conceptual lenses for addressing the question, can identify several such associated disparate conceptual lenses, the probable perspective(s) that each might yield, and can provide well-reasoned explanations for choosing the particular concept being assessed over the others for addressing the question or application. • In applying the concept to a particular context, can balance and orchestrate the various generalizations that constitute the concept according to the particular question being considered, explaining why some are more and others are less productive or insightful, and orchestrating the generalizations strategically and purposefully to create a coherent and productive approach to the question. • In applying the concept to a particular context, can describe the changes among the context's elements, events, and relationships to produce explanations, predictions, inferences, and causalities within the structure of the various generalizations chosen to approach the problem. • Can take advantage of opportunities that might arise in the course of problem solving, critical thinking or reasoned decision making to apply the conceptual lens in a creative, surprising, humorous, or particularly insightful manner. • Can explain the distinctions between the concept and other closely related concepts, giving multiple and varied examples and applications that illustrate the differences, including the use of similes, metaphors, and analogies. • Can use the concept for a self-designed and self-directed, long-term inquiry investigation, design task, or performance.

LEVEL OF UNDERSTANDING	PERFORMANCE INDICATORS
5: Creative Understanding	• Can orchestrate multiple concepts around the concept in question in many different contexts and situations. In other words, can delineate, combine, interweave, juxtapose or otherwise connect multiple concepts or concept fragments in a creative, de bono, productive, humorous perspective on any manner of situations, contexts, or applications. • Can orchestrate multiple concepts in combination with contexts and topics that are unfamiliar and of which little specific detail or vocabulary is known. • Can draw broadly from many different and varied concepts while keeping an orchestrated focus on the concept in question. Imagining the combination of the multiple concepts as the musical "key" in which such a creative conceptual ability is demonstrated, the student can switch keys and focus on a different concept that includes (as an attribute) the concept that is in question. So the student can use the concept as both the primary key or as a component of a different conceptual key. • Can use multiple concepts for a self-designed and self-directed inquiry investigation or design task. Given a particular phenomenon, context or question, can pose questions from several different conceptual perspectives and describe how different perspectives would result in different investigations or designs.

ANNOTATED REFERENCES ON CONCEPT-BASED EDUCATION

Novak, J. D. and Musonda, D. (1991). A twelve-year longitudinal study of science concept learning. American Educational Research Journal, 28(1), p. 117 - 153.

> Students in early primary grades were divided into two statistically significant groups to test the effectiveness of concept-based curriculum in science. The treatment group was instructed for a period of several months using a concept-based curriculum, while the control group was taught a conventional, fact-based curriculum. With no other treatments, both groups were tested for scientific understanding and problem-solving ability every two years until graduation from high school. Even after twelve years, the treatment group showed significantly better retention, depth of understanding, problem-solving ability and classroom performance.

Gagne, Robert M. (1985). The conditions of learning (4th ed.). New York: Holt, Reinhart and Winston.

> This is one of the more important texts that analyzes the processes of problem-solving and critical thinking. Drawing from a large body of academic research, Gagne defines concepts as those mental constructs common to these higher thinking processes. Much of the text is devoted to how students learn and use concepts.
>
> "In a review of research on the involvement of cognitive studies in problem solving, White and Whittrock (1982; unpublished manuscript of master's thesis completed by Gagne's students) found evidence that ... learners who use concepts to solve problems are better off than those who deal only with facts." (Gagne, 1985. p. 145)

Karplus, R., and Thier, H. D. (1967). A new look at elementary school science. Chicago: Rand McNally.

> An in-depth explanation and analysis of an elementary science curriculum that is concept-based, with numerous descriptions of students' superior performance compared to conventional curricula.

Jones, B. F., Palincsar, A. S., Ogle, D. S., and Carr, E. G. (1987). Strategic teaching and learning: Cognitive instruction in the content areas. Alexandria, VA: Association for Supervision and Curriculum Development.

> Summary and discussion of expert-novice research showing that experts use a concept-based approach to problem solving, whereas novices use a fact- or topic-based approach.

Taba, Hilda. (1966). Teaching strategies and cognitive functioning in elementary school children (Cooperative research project). Washington, DC: Office of Education, U.S. Department of Health, Education, and Welfare; San Francisco: San Francisco State College.

> Using a controlled experiment involving 24 teachers, Taba tested the effectiveness of concepts for organizing elementary school social studies. She found that students who used conceptual organizers demonstrated equal command of the factual content while demonstrating significantly greater critical thinking abilities compared to students who experienced the conventionally taught curriculum.

Smith, Edward L., Blakeslee, Theron D., and Anderson, Charles, W. (1993). Teaching strategies associated with conceptual change learning in science. Journal of Research in Science Teaching, Vol. 30, No. 2, pp. 111-126.

> This formal research study compared the effects on student learning of a concept-based approach with a conventional approach to teaching seventh grade units on photosynthesis and cellular respiration. Two groups of teachers agreed to teach towards the same set of generalizations for each unit, with one group using conventional texts, resources, lab activities and classroom strategies. The other group of teachers used specially written teacher guides and student materials that required them to use concept-based instructional strategies that clearly focused on developing a transferable understanding of the concept of energy transformation as described in the agreed-upon generalizations. All teachers were observed for at least half of the lessons devoted to the units, and frequency counts were tabulated on 15 different instructional strategies associated with concept-based instruction. All instructional materials and student responses were collected and frequency counts were tabulated according to 15 parameters also associated with the concept-based education model. All students were administered the same pre- and post-tests that had been previously validated for the agreed-upon generalizations.
> RESULTS: 23 of the concept-based instructional strategies and parameters had a statistically significant effect on student performance. Two parameters not usually associated with concept-based education, open-ended questioning and factual-recall questioning, had negative impacts on student learning. The highest positive effects came from teacher presentations of advance organizers describing and summarizing the conceptual context at the beginning of each unit, from the teacher's repeated references to the generalizations, and from the teacher's descriptions of applications and illustrations of the concept drawn from everyday student experiences. "The results support the claim that the recommended strategies help to promote conceptual change learning (p. 122)… [The results] seem to us to support another important contention: The conceptual change teaching strategies that we described are more powerful in combination than they are in isolation. Teachers who used only a few of the strategies successfully showed little improvements in student achievement. Thus, conceptual change teaching should probably be thought of as a coherent approach to teaching rather than as a collection of individually useful strategies" (p. 124).

Novak, Joseph D. (1977). A theory of education. Ithaca, N.Y.: Cornell University Press.

This is the seminal text for the concept-based curriculum model. It bridges the gap between cognitive theory and educational practice.

"Although concepts change in time, and may vary from culture to culture, a person's grasp for a field's concepts is the basis for understanding in that field.... This view is at once optimistic and pessimistic. It is optimistic in that education to enhance human understanding can be a focused, deliberate effort to enhance the number and quality of concepts people have; it is pessimistic in that there is no single mental strategy that can be applied wholesale to all new learning tasks." (Novak, 1977. p 61)

Concept-based learning has three important advantages: "First, knowledge... is retained longer - much, much longer in many instances. Second,... [it] adds to the capacity for easier subsequent learning of related material. Third, [it] facilitates new related learning even after forgetting has occurred." (Novak, 1977. p. 85)

" Problem solving ability [is] dependent upon the adequacy of specifically relevant concepts in the student's cognitive structure.... This ability [is the] capacity for developing and using concepts." (Novak, 1977. p. 217)

"Creative behavior... occurs when an individual makes unique associations across concepts" (Novak, 1977, p. 110)

"No curriculum theorist in the past has shown the relevance of learning theory to the design of curriculum.... If we can come to understand [concept-based] learning processes better and if we learn to apply this knowledge in the design of new instructional programs, education can be quantitatively and qualitatively much better than it has been.... Progress in [education] similar to the progress we have observed in science and associated technologies can be made." (Novak, 1977. p. 134, 190, 191)

Ausubel, David P., Novak, Joseph D., and Hanesian, Helen. (1978). Educational psychology: A cognitive view. New York: Holt, Reinhart and Winston.

This text contains the most complete and detailed explanation of the cognitive and developmental theory and research upon which concept-based education is built. It derives and explains the model in great detail from extensive research carried out by the authors as well as referencing an 82-page bibliography of research and references.

Novak, Joseph D., and Gowin, D. Bob. (1984). Learning how to learn. New York: Cambridge University Press.

This is one of the first texts to apply concept-based curriculum to classroom practice. This text introduces the technique of concept mapping, created by one of its authors, Joseph Novak.

"Much of the educational reform movement... was an attempt to get away from rote learning in schools by advancing instructional programs that encouraged discovery, or inquiry learning. Well intentioned as these efforts may have been, they did little to increase the meaningfulness of school learning" (p. 7)

"Many students classified as 'learning disabled' are really bright children who lack the skill and/or motivation for rote learning, but who can move to the front of the class when they are given an opportunity for [concept-based learning]". (p. 41)

"Nearly all students, from age 4 or 5, are capable of what Piaget called fully formal operational thinking, if they have an adequate framework of relevant concepts." (p. 144)

Erickson, H. Lynn. (1995) Stirring the head, heart, and soul: Redefining curriculum and instruction. Thousand Oaks, CA: Corwin Press.

Erickson, H. Lynn. (1998). Concept-based curriculum and instruction: Teaching beyond the facts. Thousand Oaks, CA: Corwin Press.

Through both of these books, Erickson describes how concept-based curriculum is capable of delivering the high student performances described in the national standards for the four major subject areas (math, social studies, science, and language arts). Both books emphazise classroom implementation, drawing from Erickson's extensive experience working with hundreds of schools across the country.

Anderson, L. W. and Krathwohl, D.R. (2001). A taxonomy for learning, teaching, and assessing; A revision of Bloom's taxonomy of educational objectives. New York, N.Y.: Addison Wesley Longman.

This revision of Bloom's taxonomy discusses and validates the original Taxonomy from multiple perspectives gained from experience and research drawn from the nearly 50 years since the original's publication and from across a range of fields. Many people reduce this important book to a suggestion it makes that has taken hold, and that is the addition of *Creativity* to the top of the Taxonomy, expanding it to six levels, each defined at sub-levels and sub-sub-levels. The synthesis of ideas around Bloom's taxonomy presented in this book is an emphatic support for defining higher order thinking skills as the ability to transfer conceptual knowledge that is carefully defined. The authors show over many examples how the many possible modes and methods of such conceptual transfer, in other words, the intellectual skills and processes described by the Taxonomy, can be organized into an increasing hierarchy of abstractness, complexity and subtlety. These authors also provide ample description and support for the detail of conceptual knowledge, with a structure that is precise and definable, albeit unique for each discipline.

"Two of the most important educational goals are to promote retention and to promote transfer (which, when it occurs, indicates meaningful learning)." p. 63.

"We describe our six cognitive process categories:… one that emphasizes retention and five that, although they may facilitate retention, emphasize transfer." p. 65

"Disciplines have different paradigms and epistemologies for structuring inquiry… and different ways of conceptualizing and organizing subject matter." p. 52

Eylon, B.S., and F. Reif. (1984). Effects of knowledge organization on task performance. Cognition and Instruction, 1:5-44.

Dufresne, R.J., W.J. Gerace, W.J. Leonard, J.P. Mestre, and L. Wenk. 1996. Classtalk: A classroom communication system for active learning. Journal of Computing in Higher Education, 7: 3-47.

Leonard, W.J., R.J. Dufresne, and J.P.Mestre. 1996. Using qualitative problem-solving strategies to highlight the role of conceptual knowledge in solving problems. American Journal of Physics, 64: 1495-1503.

This research describes how student performance on recall and on solving physics problems is significantly improved when the knowledge they are taught is organized hierarchically. Their performance also greatly improves when they are required to first perform a conceptual analysis of a problem. This research also showed how students perform significantly better when they solve problems first by identifying the most applicable concept, justifying their choice, and then describing the process they would follow of applying the concept to the specifics of the problem. Structuring content knowledge hierarchically is a useful strategy for helping novices both recall knowledge and solve problems.

BSCS, (2000). Making sense of integrated science – A guide for high schools, Colorado Springs, CO: BSCS.

Particularly in the sciences, concept-based curriculum is very close to integrated curriculum. This report contains numerous passages that discuss the critical importance of conceptual coherence for meeting the needs of a diversity of students, for students to be "successful on the increasing number of statewide assessments" (p. 12), and particularly for the deep conceptual understanding and ability to transfer knowledge that most educators strive for, even if the assessment of such abilities is still an inexact science.

Comfort, Kathy. (2000). How do we assess learning in integrated science? In *Making sense of integrated science – A guide for high schools*, Colorado Springs, CO: BSCS

Beginning with a universal definition of literacy, Comfort shows how it leads to the measurement of "students' ability to demonstrate understanding of the concepts that are connected and integrated among the science" (p. 52). Although examples are drawn from the sciences, the article's main theme applies much more widely: The effectiveness of an integrated or inter-disciplinary curriculum is measured in conceptual terms.

Rutherford, F. James. (2000). Coherence in high school science. In *Making sense of integrated science – A guide for high schools*, Colorado Springs, CO: BSCS.

Rutherford argues that a conceptual organization is needed for a curriculum that no longer follows the traditional lines between subject areas. "Integrated courses have no ready-made framework for creating coherence, and so it must deliberately be built into them…. Every major concept that appears needs to be linked logically to evidence supporting it and to related concepts…. A new generation of high school courses is needed that feature both integrated content and conceptual coherence."

Bransford, John D., et al. (1999). How people learn: Brain, mind, experience, and school. Washington, D.C.: National Academy Press.

This report brings concept-based education to the forefront of curriculum design. It clearly establishes that concept-based curriculum design must be the foundation for educational programs focused on the higher thinking skills, the transfer of knowledge, problem solving, and critical thinking. The report was commissioned by the U.S. Department of Education, requesting the National Research Council to appraise the scientific knowledge base on human learning and its application to K-12 education. They canvassed the research literature in the cognitive sciences, developmental psychology, neuroscience, anthropology, and research on learning in subject areas such as science, math, and social studies. Most of the major curriculum development projects funded by both the National Science Foundation and the Department of Education are now using this report as the basis for designing instructional materials and programs that will become available over the next decades.

"Learning must be guided by generalized principles in order to be widely applicable… Transfer most likely occurs when the learner knows and understands underlying principles that can be applied to problems in new contexts."

"The research… shows clearly that "usable knowledge" … is connected and organized around important concepts."

"The transfer literature suggests that the most effective transfer may come from a balance of specific examples and general principles, not from either one alone."

"Hierarchical structures [of knowledge] are useful strategies for helping novices both recall knowledge and solve problems… Helping students to organize their knowledge is as important as the knowledge itself, since knowledge organization is likely to affect students' intellectual performance."

"Outstanding teaching [is] … knowledge centered in the sense that the teachers attempt to help students develop an organized understanding of important concepts in each discipline."

Wells, Malcolm; Hestenes, David; Swackhamer, Gregg. (July, 1995). A Modeling Method for High School Physics. American Journal of Physics, 63(7), p. 606-619.

Findings of the *Modeling Workshop Project* (1994-99): Final NSF project report, November, 2000.

These reports describe and provide compelling data on student academic performance in physics resulting from the use of a concept-based curriculum. The first report focuses on the development of the curriculum and its implementation by one of the developer teachers. The second reports on the performance of students of over 600 teachers. Using excellent pre-and post-tests of student achievement in comparison with many different control groupings, both reports show stunning improvements. Aggregated results show at least a 10 percentage point increase in student performance. "Students' gains in understanding of the force concept *typically doubled to tripled* (original emphasis), [and] most teachers' understanding of the force concept improved to mastery level [regardless of prior science training]."

Student improvement was also shown to be directly correlated with the degree of implementation of the curriculum. Even the students of those teachers who had only used parts of the curriculum showed a significant proportional improvement. The benefits of the curriculum were not lost on the teachers: "More teachers implemented the method more fully in succeeding years of their participation in the program, and their students' gains went up accordingly."

The reported research also shows the additional effect of a concept-based curriculum on top of a student-centered, inquiry approach to instruction: "The data… strongly supports the conclusions that [the concept-based] method is a considerable improvement over [the] cooperative inquiry method and clearly superior to the traditional method." Under-prepared students were also shown to benefit particularly from the approach, and long-term retention of learning months after instruction was also demonstrated.

An interesting result of the research was also to show that for both traditional and inquiry-based instructional approaches, there was no relationship between student learning and a teacher's experience and academic background. However, teachers using a concept-based approach generally showed a steady improvement in their students' performance over the three years of data included in the second study.

System Dynamics Curriculum. Home web site http://sysdyn.mit.edu/ PK-12

Newsletter: The Creative Learning Exchange http://www.clexchange.org/cle_homepage.html.

The System Dynamics in Education Project (SDEP) is a group of students and staff in the Sloan School of Management at the Massachusetts Institute of Technology, working under the guidance of Professor Jay W. Forrester, the founder of system dynamics. There are presently hundreds of teachers across the country, and world, using system dynamics as an approach to teaching all manner of topics from across the subject areas, with excellent results. (See the edited listserv k-12sd@sysdyn.mit.edu to follow an active discussion.) System Dynamics is a "conceptual model" with clear and explicit components drawn from two basic concepts: Change/Process, and Regulation. As a curriculum, it is an excellent model of how a concept-based approach looks in the classroom. It is also an illustration of how a well-defined, transferable concept such as Change or Regulation can provide profound insights, even for the youngest students, into an astonishing variety of topics. This curriculum program shows how students can build sophisticated skills, such as graph construction in first grade and computer modeling in third, through the active application of these concepts to specific questions and phenomena. By focusing on one conceptual "package" throughout the K-12 span, System Dynamics also illustrates the development in understanding of such a conceptual unit over time, starting with cooperative, inquiry-based discovery of the basic generalizations in the early elementary grades, and spanning to sophisticated computer modeling of highly complex systems.

Ausubel, David P. (2000). The acquisition and retention of knowledge: A cognitive view. Boston: Kluwer Academic Publishers.

In this short yet dense book, David Ausubel focuses on classroom learning, with particular attention paid to secondary classrooms where reception learning predominates. Ausubel, whose Assimilation Theory of learning largely began the cognitive revolution in educational psychology almost fifty years ago, has finally collected in one book the arguments and research on what it means to teach and learn creative problem solving and critical thinking within the realities of classroom learning. Recognizing that open inquiry and discovery have a role to play, particularly at the early elementary level, this book "contains an exposition and elaboration of the major principles of meaningful reception learning and retention" (p. 38). With barely a statement made without reference to supporting research, Ausubel makes a strong argument that educationally powerful conceptual structures can be derived from the existing structure and developmental changes of the human intellect. He proposes that classroom reception learning organized and sequenced according to conceptual structures generates "*long-run* (author's emphasis) acquisition of stable and usable bodies of knowledge (and of intellectual skills) and … the development of the ability to think systematically, independently, and critically in particular fields of inquiry" (p. 31). He discusses how "provocative, meaningful, and developmentally appropriate instruction" stimulates "the development of motivations and interests that are currently non-existent" (p. 33). This book provides ample research and rationale for basing classroom teaching and learning on conceptual structures. It is also the rare, if not only, convincing model for designing teaching and learning that honors and even exceeds the intellectual and creative demands that the twenty-first century is requiring of high school graduates.

Finley, Sandra J. (September, 2000). Instructional coherence: The changing role of the teacher. Austin, TX: Southwest Educational Development Laboratory.

One of the major features of Concept-Based Education (CBE) is that it places a teacher's classroom practice at the beginning and center of reform efforts. CBE is intellectually demanding in that it asks teachers to consider deeply the nature of the knowledge that they are teaching and what it means to understand such knowledge. This report provides an excellent rationale and explanation for why and how student learning will only be significantly improved by reforms that focus on classroom practice and see "professional development as teacher learning." The systemic reform issues that surround classroom practice are necessary but not sufficient, nor even pre-requisite, for affecting student learning. The report states that "reforms will have little impact on how and what children learn unless there also are changes in the 'core' of educational practice, that is, in how teachers understand knowledge and learning and how they operationalize their understandings. So, teacher understanding becomes a critical piece in reform." The report provides an excellent discussion of what various approaches to professional development imply about teachers' own learning and their professional role as knowledge experts, as opposed to information experts. For example, effective teacher collaboration is "about teaching and learning that is grounded in the specifics of the classroom." This view of professional collegiality is embedded throughout the Concept-Based Education professional development program.

Hake, Richard R. (1998). Interactive Engagement versus Traditional Methods: A Six-Thousand-Student Survey of Mechanics Test Data for Introductory Physics Courses. American Journal of Physics, Vol. 66, p. 64 – 74. Available on-line at www.physics.indiana.edu/~sdi/ajpv3i.pdf

This detailed research uses one of the largest samples of subjects of any research on the effectiveness of classroom strategies for improving student learning, comparing the performance of 6542 students in high school and college physics classes using a concept-based approach to 2084 similar students taught in "traditional" courses. Measuring the conceptual and problem-solving performance of students in mechanics, the research found that students in concept-based classes achieved an average gain of almost two standard deviations above those in traditional classes. The author concludes that the use of concept-based methods in classrooms can increase mechanics-course effectiveness well beyond that obtained in traditional practice.

GLOSSARY

Bloom's Taxonomy	Basic thinking skills: 1) Knowledge (Memory) 2) Comprehension Higher thinking processes: 3) Application 4) Analysis 5) Synthesis 6) Evaluation 7) Creativity
Concept (see also **Transferable Concept)**	A perceived regularity in entities or processes. A generic idea with more than one example. Since specific instances such as *Spot the dog* or *Edna the hurricane* are not concepts, most of the words in a language are concepts.
Content	A catch-all term that is understood to be the "opposite" of processes and/or learning skills. Content consists of a mixture of both specific topical or contextual information and concepts, with little distinction made between the two. Examples: Literary context, mechanics, heritage, consumer math
Critical Thinking	An intellectual process focused on a question. Critical thinking is often thought of as higher or high-level thinking. However, critical thinking depends upon, and therefore includes, factual knowledge and comprehension, often referred to as lower thinking. In critical thinking, all six of the thinking processes identified by Bloom (see Bloom's Taxonomy) are orchestrated in a fluid, intellectual manner that can be characterized by the interplay of generic concepts skillfully combined with specific topics. The infinite ways concepts and topics can be combined constitute the long list of process skills. Critical thinking is largely a progressive process that ends when and how the thinker chooses, with no reason to pause or stop inherent in the development of the intellectual journey.
Inquiry	Inquiry is a self-motivated, self-directed process. It seeks answers to questions by applying prior knowledge to observations and analysis of the circumstances or entities that elicited the question. Inquiry includes algorithms and formulas, both generic and specific to certain types of questions. Yet it is ultimately a creative intellectual process. A question instigates a unique, often interactive synthesis and re-evaluation of prior knowledge and new experience. Inquiry results in a satisfying, enjoyable feeling of intellectual accomplishment and growth.

Glossary – continued:

Generalization	Also called an enduring understanding, basic principle, core knowledge, or, at times, a big idea. A generalization is a propositional statement that links two or more concepts, sometimes includes specific topics or contexts, and is stated as an assertion or conclusion. The understanding that underlies a transferable concept is described in terms of generalizations. A generalization is a statement of a fundamental aspect of the concept useful to generating insight to questions.
Literacy	An educational goal focused on developing skills and knowledge that are widely useful both for themselves and/or because they are essential for learning how to learn. As educators, we strive for literacy in math, science, and social studies, as well as language arts. Sometimes a particular package of skills and knowledge is identified as being "essential skills," forming a good definition of literacy. Literacy contrast with professional development, in which the student is assumed to be preparing for a particular adult role, such as a scientist, engineer, accountant, stock broker, politician, business leader, media specialist, writer, etc. Literacy attempts to focus on generic, flexible knowledge and abilities that can form a useful, efficient platform from which to launch into all manner of different careers.
Problem Solving	Very similar to critical thinking. Problem solving is also an intellectual process focused on a question. However, the question is usually one that implies some type of answer or solution: i.e. a problem. Problem solving is characterized by a problem-solution cycle. Except for trivial problems, rarely is a solution perfect, ideal or exact. Rather, a solution implies the next question or problem, re-starting a cycle often referred to as scientific method or inquiry. Problem solving progresses from plateau to plateau, and logically ends at some solution set whose uncertainty is, for the time, acceptable or unavoidable. At the smaller scale of each individual cycle, the process of going from problem to solution is the same as critical thinking.
Processes, Thinking	Often associated with (and confused with) skills, thinking processes involve some mental operation that the thinker must tailor to a particular question. All of the thinking processes can be categorized as one, or as a combination, of the four higher-order thinking processes identified in Bloom's taxonomy (see below), and all can be objectively defined as a particular method of combining a generic, transferable concept with a specific topic or context.
Skills	A catch-all term that describes what students do or perform, skills are behaviors or actions, either physical or mental. They refer to motor, social, or algorithmic mental actions that are repeated essentially the same way each time they are used. Skills are, like concepts, transferable to a variety of contexts and topics, and are categorized as one or the other of the two lower-order thinking skills defined by Bloom.

Theme	a) An umbrella term used for coordinating lessons in different subjects. The vast majority of themes are topics, with an occasional concept or process skill apparent. Examples: Circus, rain forest, hot air balloons, 1492. b) In language arts, theme is a major, super-ordinate concept that expresses the literary messages in a text. As such, it would by rights appear above in the glossary as an example under Transferable Concept. Examples: Friendship, power, gender role, race
Topic	Specific information, situations or contexts; factual; observable. In some subject areas topic information is called core knowledge. In language arts, literary genres and specific book titles generally constitute topics.
Transferable Concept	A sub-set of all concepts; a generic idea whose central quality is transferability: it can be applied to a wide variety of topics, situations, and contexts for problem solving and critical thinking through the pursuit of a question. Transferable concepts have names and can be defined in terms of their essential criterial attributes. Examples: • **Science:** Energy, temperature, interdependence, form-and-function • **Math:** Ratio, slope, property/variable, chance • **Literature**: Language, genre, literary elements • **Social Studies**: Conflict, trade, culture, custom