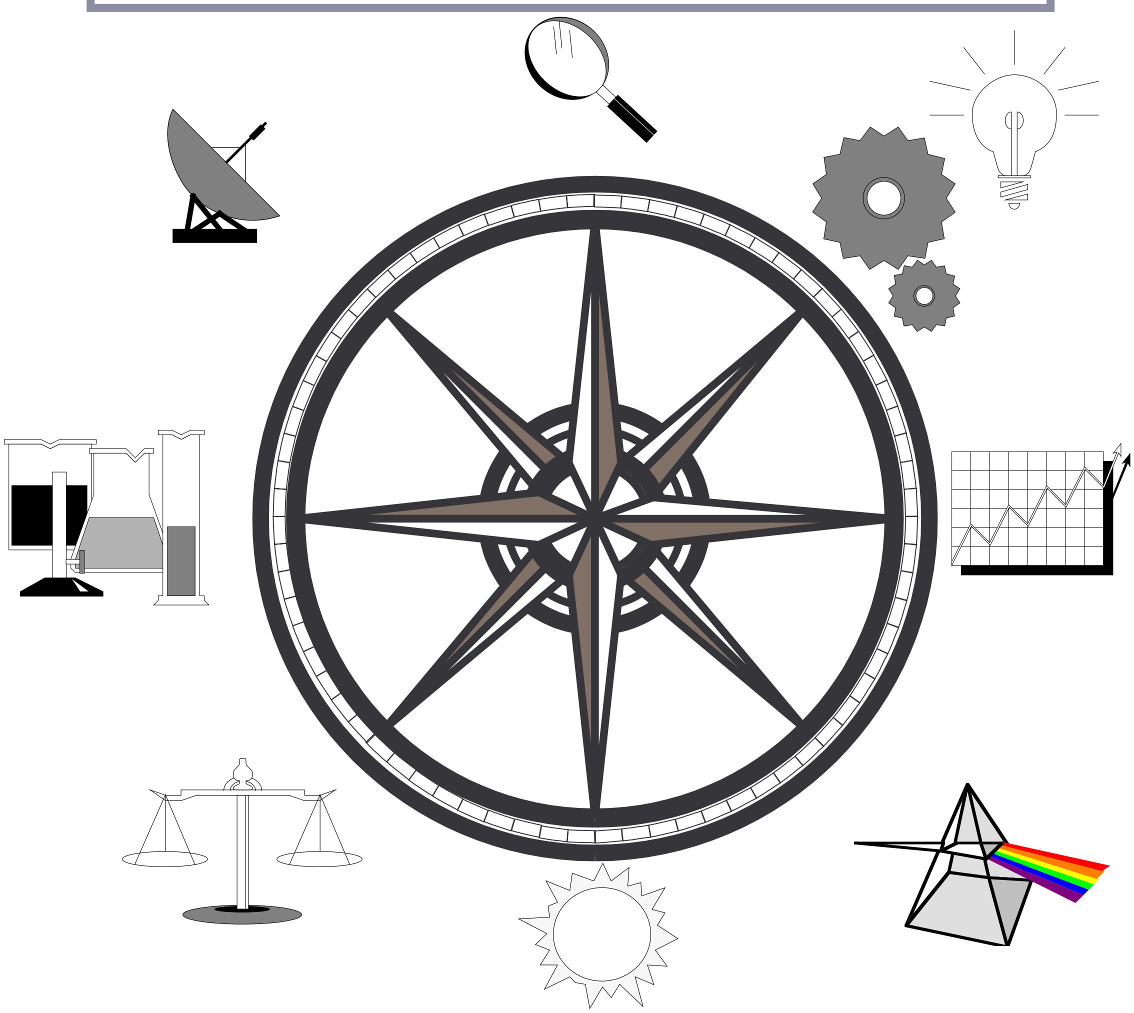
SymmetryScience*

Discovering the World By Doing Science

An Introduction to the SymmetryScience™ Method and Curriculum



Dear Teachers,

Let me introduce a wonderful new program to you, the SymmetryScience curriculum. In my work as a curriculum consultant in the Greater Boston area, I have been privileged to observe teachers delight in the clarity of its ideas and its simple lesson preparation. I have watched students become deeply involved in its experiments and journals, graphic analyzers, and embedded stories. And I have felt the relief of administrators who see in the SymmetryScience curriculum a program encompassing everything needed to bring about systemic change in science. Throughout my career as teacher, curriculum writer, and school administrator, I have despaired at the lack of continuity in our science programs. I have understood the frustration of teachers who feel ill prepared to teach science. Students have enjoyed a plethora of hands-on experiences, and excellent kits and materials have been available. But what has been missing was the "tool kit" of skills and understanding similar to those that learners acquire and use with greater and greater sophistication in the language arts and mathematics. Where were these basic building blocks in science? How were students to connect all of their disparate pieces of scientific information? Most alarming of all, how were they *learning and practicing the process of scientific inquiry?*

The SymmetryScience program has been a thrilling discovery for me. It has been the answer to all of these perplexing questions about school science programs. A gift to students, teachers, and administrators, the SymmetryScience curriculum was created with the intention of making students literate in science! Designed by bio-physicist, neurologist, and teacher Peter Bergethon to parallel the developing cognitive growth of students, the SymmetryScience program begins teaching the foundation of scientific inquiry, a Language of Patterns, as early as kindergarten. At the same time, the SymmetryScience curriculum is rich with stories of great scientists and young people who, like the students themselves, find mystery, wonder, and delight in the world around them.

Your journey as a teacher of this welcome program is about to begin. When you have your Teacher's Guide, easily understandable knowledge about science will be at your fingertips. You will not have to "know the answer", rather, you and your students will learn together a new language of science and a new way of understanding your world.

Barbara Carlson

Teachers as Scholars
Harvard Graduate School of Education

The SymmetryScience™ Program Includes:

Coordinated Science Curriculum

- Progressive, interdisciplinary, spiraling K-9 science curriculum connecting science and the humanities.

Classroom Support

- All of the materials needed to support the experimental explorations.
- Teacher's Guides, including detailed lesson plans.
- Student Science Journals, which are laboratory manuals and notebooks that provide embedded assessment and support at-home review of content.
- Progressive use of graphical organizers to promote the construction of knowledge from informal observation through concrete modeling to formal treatments of ideas and concepts.
- Interactive internet world-wide web support for teachers and students.

A Context For Scientific Thinking

- Kinesthetic exercises to use physical education, art, music, and movement to help teach physical science principles.
- Use of stories depicting the history of science in all modules to connect the stories and practice of science in a personal and human way.

Dear Reader:

Thank you for your interest in the SymmetryScience™ program. This pamphlet will provide you with a summary of the SymmetryScience program including its scientific basis, goals, and components.

Before you begin your exploration, I would like to tell you why this program was developed. I have been privileged to examine the mind at the bedside as a neurologist and explore the physics of thinking in the laboratory as a biophysical electrochemist, I have also been a teacher of medical and graduate students, night-school adults, and children learning science and nature in school or at camp. It has been a life filled with using science and art to explore the workings of the human mind.

The SymmetryScience curriculum had its beginnings in observations that I made as a professor teaching medical and graduate students. I was surprised by the lack of understanding of the fundamental scientific process, philosophical viewpoint, and conceptual knowledge in many of the expert science students I taught. All of these students could recall facts, but many could not apply them to problems of interest.

Over a decade of teaching, I developed several courses and wrote several textbooks that used the powerful scientific tools of pattern feature analysis and theoretical modeling as a way to remediate the language of science that my students lacked. These pedagogical explorations in the classroom and curriculum design were supported by my research work in intelligence modeling and by my clinical experiences at the Neurological Unit of Boston City Hospital. The tradition of cognitive neurology at the Neurological Unit greatly facilitated my understanding of how the brain uses the structures of form and language to develop into a mind.

When my daughter entered school, I started working with educators who had the same experience with their elementary students that I had with my graduate school students. I was motivated to develop a curriculum of science study based on the idea that science could be more universally understood if its intrinsic language was explicitly taught early in the educational process, much as we teach children to read and write. These were the beginnings of the SymmetryScience Program™.

The concepts at the heart of the SymmetryScience™ program development recognize that the parallel between science and written language cannot be lost. Before the school experience begins, the brain is busy learning on its own. Children begin school with a huge vocabulary and a knowledge of the syntax of spoken language. Over the same time, the brain is sampling the natural world and constructing experiences into a view of the world.

The cognitive mechanics of the brain are more magical than scientific. To provide a scientific view, I introduced a language of critical analysis (the Language of Patterns) to correct the intrinsic tendency of the mind to reach unsupported conclusions. My goal became to build a program using this Language of Patterns along with laboratory and activity-based explorations. This program was coordinated with the development of the brain. This provided a unified, structural approach to knowledge construction that has become the SymmetryScience method. Working with an enthusiastic core of teachers and schools over the last several years, we have grown into an education company dedicated to the development, design, and implementation of these science education tools.

As you read this booklet I would like to draw your attention to the philosophical core of the SymmetryScience™ curriculum that you will see in the following pages:

1) First, science is a way of looking at the world. Properly taught, science simplifies our view of the world. With mastery of a unifying language and just several fundamental concepts and strategies, the limitless diversity of the universe becomes manageable and open to us all.

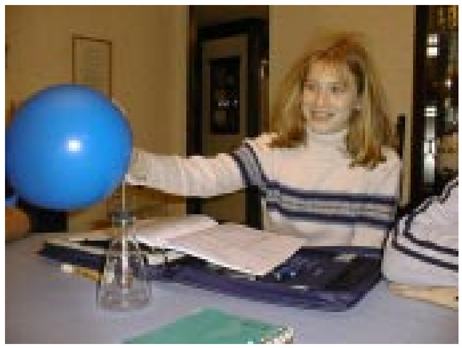
2) Active learning is work! This is true for the learner as well as the teacher-mentor. Structured discovery coordinates the construction of knowledge so that it supports and provides context for the addition of the next piece of the content puzzle. The goal of making students successful is supported through understanding. In using the principle of structured discovery, we glorify the process and seek to assure success through hard work.

3) The SymmetryScience™ program recognizes that the teacher is a central figure in the learning of every student. While ultimately every teacher strives to make the student independent, the process of achieving this independence needs to be supported through materials and professional development opportunities. Teachers who are inspired to learn, inspire students to learn! All of our materials are designed with this in mind.

The SymmetryScience program does not just teach science, it uses science to teach. I look forward to working with you and your students.

Peter R. Bergethon, M.D.
CEO and Chief Science Officer, Symmetry Learning Systems, Inc.

The SymmetryScience Program is a systemic science curriculum designed to enable everyone, students and adults, to become scientifically literate. The SymmetryScience method coordinates three ideas: how the brain works, how knowledge is organized, and what it means to be scientifically literate.



The SymmetryScience curriculum is a unique, hands-on, K-9 science curriculum designed to guide its students to science literacy. SymmetryScience is an experimentally-based program that replicates the modern scientific process. The program uses a coherent and structured series of experimental activities to allow students to gain first-hand experience with the content and concepts of modern science.

Concepts, content, context, and the methods of scientific inquiry are all taught actively in coordination as students perform hundreds of connected experiments. These experiments are arranged in research programs that connect the student to the relevant questions and the context of science over the history of humankind. In the process of discovering content, students become proficient at the scientific process as well.

The SymmetryScience curriculum combines expertise in neurology, science, and research-based teaching methods to guide the development of life-long learning tools in every student. It is a comprehensive science education system that interconnects the fields of physics, chemistry, biology, and earth/space science and makes them accessible to all.

The SymmetryScience curriculum has been designed so that the building blocks for each of the great ideas of science are introduced from the entry level upward. Scientific knowledge has its own objective organization. The organization of the scientific concepts and content are respected in the SymmetryScience program, but the program coordinates a cognitively appropriate teaching approach so that construction of these vital ideas can be started early and then refined by many examples and applications.

The SymmetryScience method recognizes that the growing, learning child explores his/her world with a growing, learning brain. Successful science education must recognize and respect the capacities and limitations of the biological brain.

The SymmetryScience program introduces a language of critical analysis early in the learning process. The SymmetryScience program is the only program to explicitly present and teach this crucial language to students. The language is introduced in kindergarten, and it is exercised and refined throughout the program. This critical analysis language provides every student with the tools and opportunity both to explore the world and to communicate and to learn from others. This defines a scientifically literate student.

The SymmetryScience view of scientific literacy is consistent with the ideals expressed in the Benchmarks for Science Literacy developed by the American Association for the Advancement of Science's Project 2061 and the National Science Education Standards.

Our Goal: Science Literacy for All

The SymmetryScience program is founded on the idea that science education is critical to a democratic and free society. By developing effective tools that move all individuals toward the goal of scientific literacy, SymmetryScience is dedicated to the freedom and creative power that a scientific viewpoint provides.

GOAL 1. DELIVER SCIENCE LITERACY TO ALL CITIZENS

Science, as a way of knowing, is the *de facto* standard in all aspects of our society. Science defines the use of evidence to verify observation and ideas in the marketplace, the courts, in art and literary criticism, and ideally in social and political discourse.

Most of us think about literacy as being able to read and write. Being literate in written language is knowing how the elements of the language (letters) are arranged by rules (syntax) to make structures on a background space (literary works in a book).

Being literate includes not only knowing the central ideas and rules, but it also requires a familiarity with some of the diverse uses of the subject. For example, to be literate in the English language includes skill in forming letters, using syntax and spelling, along with a working knowledge of certain poems, novels, dramas, and satires.

This idea of literacy applies to any area of knowledge. Science literacy is knowing how to observe, define, and describe the natural world. This includes knowing how the observations and their explanations are tested. Scientific literacy also includes being familiar with the central ideas of how the natural world works.

In a complex world, how can scientific literacy be achieved? The answer lies in our view of learning. Literacy is achieved when a few unifying ideas are understood and then are used to simplify the complexity of the world. Science literacy is mastery of the language of science and familiarity with the breadth of its content.

The design of the SymmetryScience program recognizes that active learning, through hands-on activity, asking and answering questions of personal interest, and presenting new information in the context of what is already known is effective in achieving this goal.

Goal 2. Develop a Community of Learning That Encourages the Scientific Habits of Mind

The future of our society depends on the willingness of its citizens to be actively engaged in intellectual risk taking. Such a risk-taking environment requires that every individual is capable of engaging in constructive dialogue. The SymmetryScience program emphasizes a common language that enables effective and fair discourse. This communication tool helps teachers and students learn from one another. Students learn how to anticipate and correct error; it allows them to discover and connect related ideas that might otherwise have gone unconnected.

The experimental experience makes it easy to create a positive environment in which the skills for critical analysis, discourse, and experimental skepticism can be developed. Through the extensive discovery experience provided under the discipline of SymmetryScience's structured discovery, students grow within the inquiry driven, constructively critical environment of the scientific community. This enables them to be successful in open-ended assessments and in real problem-solving in their lives.

> Science phobia is the single greatest barrier to achieving science literacy

Goal 3. Provide Tools and Strategies Through Systemic Reform

If systemic reform is to effectively change the way students learn science, it must include strategies for ensuring adult literacy. A unique feature of the SymmetryScience curriculum is that it builds scientific knowledge progressively, moving from concrete observations toward more abstract ideas. Respecting this pattern of learning allows the program to be compatible with the cognitive development of young learners.

Until educated, adults are also concrete learners and must be brought along psychologically and educationally before they can use abstraction and symbolic methods effectively. Therefore, the SymmetryScience curriculum is equally useful for training adults who are science phobic. The same program that can be used to teach children can be used to professionally develop the teachers and parents, albeit at a much different pace. The SymmetryScience professional development program allows teachers to become familiar with the program as they learn science; they then use the same set of experiences to confidently teach and guide young students along the same path. This achieves an unprecedented degree of educational efficiency in systemic reform.

The Science Behind The Curriculum

The SymmetryScience curriculum is a system that coordinates how the brain works with the way scientific knowledge is organized. The curriculum is a tool to deliver this coordinated knowledge.

The fundamental idea of the SymmetryScience method is to use scientific thinking to simplify complicated concepts. The SymmetryScience method uses expertise in neurology and in scientific knowledge to achieve this goal.

Three unifying ideas underlie the structure of the SymmetryScience curriculum:

1) The brain is a pattern analyzer and uses a **language of pattern analysis** to internally communicate about the world.

2) Knowledge construction in the mind proceeds from concrete observation through an abstract mapping process to build formal models that are highly abstract and coded. This is the process of **modeling**.

3) Human knowledge is constructed by assembling elements into structures. The immense richness and diversity of the world can be explored by considering the unifying ideas and appreciating the complexity of their arrangement. Organizing the curriculum to discover these relationships is called **structured discovery**.

> The world should be described
> in the simplest terms possible,
> but no simpler.
> Albert Einstein

Concept # 1. The Language of Patterns

The most important simplifying idea that runs through the SymmetryScience curriculum is the central role of the **Language of Patterns**. It is a unique feature of the SymmetryScience method. Using this language is fundamental to success in science and critical thinking.

Extensive research in neurology, neurophysiology, and cognitive neuroscience has been done to understand how the brain perceives and learns. A summary of this research shows:

- When the brain observes its world, information is extracted in terms of pattern features. For example, the image of a dog seen by your eye is broken down by the brain into lines, curves, contrasts of light and dark, and motions against a background.
- The brain reconstructs pattern information into a representation or model.
- Brain operations involve a pattern analysis-modeling cycle.
- The brain ”knows” something when it builds a model of an object, action, or idea from its pattern features.

This type of analysis is in contrast to a digital computer, which scans and processes information point-by-point, thus making a list. A digital computer makes and memorizes lists easily, but it is not particularly good at recognizing patterns.

If we consider the example of the dog above, the brain extracts the information from an image in terms of the **features** from which it is formed.

These features are composed of the **elements** (lines, curves, contours, etc.), the **rules** arranging the elements, and the **background space** into which the elements are arranged. These features are what we will call the **pattern of the image**.

Any object or system of objects can be fully characterized by a description of its pattern features, which include elements, rules, and background.

- **Elements** are objects in a system that are defined by certain properties (color, shape, texture).
- A **rule** defines the relationship between elements. Rules order the elements into arrangements. These arrangements are the **structure** of the system.
- The **background** is the space or context in which the elements and their arrangement occur.

Using these ideas, a language useful for analyzing all information can be described as the Language of Patterns. The **Language of Patterns** is used to describe the construction of information and knowledge in terms of a pattern's features. It is a remarkably simple language; it is also one of enormous power and versatility.

The Language of Patterns is one of the most useful simplifying concepts available for the critical study of science or any other subject. Once mastered, the Language of Patterns can be used over and over to characterize, explore, and understand any system of interest at multiple levels.

While the Language of Patterns is a foundation tool for learning critical analysis in the arts and science, it is also the ideal preparation for students in technology and computer programming. The same principles and vocabulary in the Language of Patterns are used throughout computer programming (especially object-oriented programming) and technical analysis. Thus the Language of Patterns is an essential and practical part of every school's technology program. It is a core connector between science and technology.

Concept #2. The Construction of Knowledge

Research in cognitive development has been used to coordinate the SymmetryScience curriculum with how the brain perceives and learns. The SymmetryScience method uses a unified, cognitive model of how the nervous system gives rise to the learning mind. This model provides a cogent framework onto which a curriculum may be formed and then assessed.

It is well appreciated that the human brain grows and develops in a fairly predictable pattern. This means that children think and learn differently at different times of their lives. While all teachers recognize the wide variability of these stages, the general trends are well supported by extensive evidence. This research on the cognitive development of children has been used in the development of the SymmetryScience program.

The brain organizes pattern feature analysis in a progressive and predictable development; information is treated concretely first and then progressively abstracted. This concrete-to-abstract knowledge construction pattern is influenced by two factors. One is the biological development of the growing brain. The brain progressively acquires the biological capacity to perform abstract operations on concrete observations from infancy to early adulthood. The other factor influencing knowledge construction is the level of education and psychological development of the individual. Adults who may be fully biologically developed still may be psychologically concrete. With education and learned critical thinking strategies, adults can move from concrete thinking to abstract rational processing.

Human learning follows this pattern of biology and psychology; any useful curriculum must coordinate the internal structure of the subject to the concrete-to-abstract learning pattern of the brain. The SymmetryScience curriculum substantially extends the coordination of cognitive neuroscience beyond the ideas of "learning stages" used by other programs by presenting a clear vision of how the ideas and principles of science connect together. It does this through an active process of model-building and experimental experience.

In the SymmetryScience program, an endpoint for science literacy is a degree of conceptual understanding that builds reasonably accurate and continuously accessible models of scientific ideas.

For example, the physical concept of heat as the random thermal motion of atomically small particles can be formally represented in the early grades as the back and forth jiggly movement of particles in a defined background space such as the classroom or inside a circle formed by classmates. The SymmetryScience program uses children and adults in a classroom and calls them Kidolecules™ .

The concept that heat is motion of particles is easy to grasp in this way. The random motion of being "jiggly" is, in fact, accurate enough for a respectable literacy in the subject of heat energy. Still, this physical model can be easily advanced to a higher level by exploring a random walk process and relating the degree of "jiggliness" to the Boltzmann constant. Such pedagogical models have been used with success in graduate studies of physical chemistry!

In the SymmetryScience curriculum, the scientific models described above are arranged so that conceptual understanding is accessible at each level, and then when biological maturity or formal education is in place to advance to a higher degree of symbolic formalism, students may proceed as their interest and need require.

Concept #3. Structured Discovery

Overcoming Science Phobia and Misconception

At the end of the twentieth century, the expectations of what a citizen in our society must know about the world have changed. Each citizen will need to participate in an era of continuously expanding information growth. Full participation in this future will require a scientifically literate population. The mission of the current science literacy movement is to ensure that individuals will be able to critically examine, communicate, deliberate, and implement decisions based on a wealth of evidence. This requires a scientific view of life.

Two serious manifestations of scientific illiteracy are commonly encountered by scientists and science educators. One is a widespread fear of science (or science phobia). The second is a tendency to develop misconceptions about scientific concepts that affects even the most serious students of science.

Science phobia prevents individuals from taking the intellectual risk needed to engage in scientific discovery; it is the single greatest barrier to developing a scientifically literate citizenry. Science phobia results from the dread that most people feel when confronted by the complicated language and symbols that represent scientific knowledge. Many people are exposed to science in a blizzard of facts, names, and symbols to be learned by rote memorization, when in fact, science is actually a way of exploring, organizing, and simplifying the world. The struggle to learn by rote memory and passively delivered facts can lead to frustration and a sense of failure. On the other hand, simply observing and exploring our universe leads to easily formed misconceptions.

Students and even experienced researchers often construct scientific misconceptions. Even when demonstrated as incorrect, these misconceptions are very resistant to correction. The history of science is filled with examples that demonstrate that careful observation without disciplined methods of experimental control lead to incorrect conclusions about the workings of the natural world. It is in the correction of such misconceptions (such as the earth is flat - a very common first impression) that modern experimental science has been so successful.

The brain is a remarkable pattern recognition engine and a superb system for categorizing. Biological evolution has formed this powerful system for pattern exploration and classification, but at the expense of a tendency toward bias and prejudice. The brain is inclined to lock onto the most "obvious" image or cause-and-effect explanation for an observation. Thus, uneducated adults and developing children can easily suffer from "diverted intuition" which may lead them down an incorrect path. Once a particular viewpoint is learned, the same tendency to jump to conclusions leads to a tendency toward bias and prejudice that makes revision of knowledge difficult and tedious.

Besides leading to science phobia, simple passive presentation of information to be learned in a rote fashion tends to be inefficient and does not easily support application of the retained information across a curriculum of learning. Active learning is clearly preferred from a pedagogical and neurological standpoint. Active exploration, however, carries with it the risk of constructing concepts that are at odds with the actual behavior of the natural world. Once misconceived, these concepts are very difficult to reconstruct again, leading to a very high degree of inefficiency in understanding. Simple hands-on and inquiry-based constructivist approaches to science are probably just as inefficient in the long run as passive rote learning.

The SymmetryScience curriculum is designed with these tendencies of the brain in mind, recognizing that the commitment to the benefits of active hands-on experimentation must be balanced with experiences that promote understanding and not confusion or frustration.

Active Learning Through Structured Discovery

The SymmetryScience program seeks to balance the formalism and structure found in the relatively ineffective passive/rote teaching styles with the more effective, active and constructivist styles of teaching. The ideal teaching model is a balance in which active exploration is constrained to make the student successful in his or her explorations without forming misconceptions. The SymmetryScience program calls this type of balanced curriculum design **structured discovery**. Our understanding of neuroscience and learning supports active engagement within structured learning experiences.

Structured discovery designs the curriculum so that each science concept to be learned can be discovered in a series of coordinated, experimental activities that provide structured, active learning with the needed, repeated experience to foster understanding. Laboratory and discovery experiences are linked together so that a concept is constructed out of structured laboratory experiences that mimic the actual scientific discoveries.

Structured discovery provides the novice and inexperienced student and teacher with a controlled scientific environment in which many of the paths to error are blocked. This improves the opportunity for successful and satisfying discoveries that keep the novice experimenter coming back for more experience and practice. At the same time, an active construction of scientific concepts is ongoing. As sophistication grows, the experimental experience can be made less structured and the student can take more intellectual risks. With the substantial experience gained through the structured discovery program, students become confident in their scientific dexterity. At the same time, they are able to practice a skeptical and critical outlook on their own experimental activities.

Developing Scientific Habits of Mind

The Progression of Inquiry and the Language of Patterns

The SymmetryScience™ method is a science curriculum that recognizes the structure of scientific knowledge and coordinates this knowledge with the way the brain perceives the world. SymmetryScience™ relies heavily on the central role played by patterns and pattern recognition in teaching science and developing a literacy of science. Learning and using the scientific method as a fundamental habit-of-mind is a central goal of the SymmetryScience curriculum. The scientific method must be learned in stages as a child grows and develops both neurologically and educationally. The SymmetryScience curriculum stages this learning path as a *Progression of Inquiry.* The SymmetryScience curriculum spirals, in that the content and process taught in the early years are constantly practiced and reemphasized in later years. To unify and provide consistency in the learning stages, SymmetryScience uses a common language to express what is observed, described, hypothesized, and tested. We call this language *The Language of Patterns*.

The Language of Patterns

Scientific inquiry is a great way to systematically learn about the world. A special "language" makes thinking systematically easy. This "language" can be used in each step of scientific inquiry to say what is observed, described, modeled, and tested. This "language" is called **The Language of Patterns**. The Language of Patterns is simple. The Language of Patterns describes any observation, model, or experiment using several simple terms:

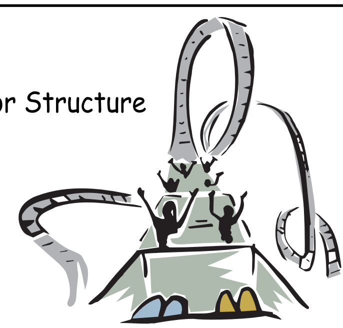
- **Elements** - parts that make up things.
- **Rules** - how the parts of things are arranged.
- **Background** - the space where the parts are.
- **Systems** or **Structures** - the things themselves.
- **Change** - how systems become different over time.

The Language of Patterns can be used to describe any pattern, or any object, or any group of objects. The basic questions asked by the Language of Patterns are:

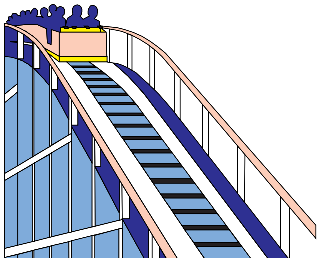
- What are the properties of the system?
- Who and what?
- How and where?
- Where is it going?

This is the Language of Patterns. It is the language of science.

Example



Here is an example of how the Language of Patterns is used. In this example, the object or system we want to describe is a ride on a roller coaster. The ride is called a **structure** or a **system**. Any object, thing, or group of objects can be called a structure (or system).



The Who or What of the object or system are called the **elements**. Elements are the parts that make up things. Here, the elements are the riders in the car, the other people on the ride, and the track.

How the elements are arranged depends on certain **rules.** One rule of this example is: each seat in the car has two people. Another arranging rule is that some parts of the track are higher than others. Still another related rule is that the car is pulled down the track from high to low by gravity.

The **background space** is the place where the object is. In this example of the roller coaster ride, the background space is the space that holds the roller coaster and the tracks, which is the amusement park. If the background space was a coal mine, the same cars, tracks, rules and even people would be a very different system.

The Progression of Inquiry and Modeling

A central idea in the SymmetryScience method is a recognition of the important role played by models and modeling in human learning. Modeling is the representation of something using a partial accounting of its features and properties. Modeling is the process by which abstract representation and symbols are used to represent complicated systems. A model, even though it is a partial representation of the real world, is acted on and treated as if it is the original. A "good" model provides a satisfactory representation under these conditions.

Modeling in the Brain

Modeling is the coordinating link between the human brain and learning, the practice and structure of scientific knowledge, and science education. When the brain regards its world, it extracts certain features. The brain uses these pattern features to construct a series of interrelated internal models at several levels:

Descriptive or representational models - describe what parts there are and how they go together.

Explanatory models - describe the cause and effect relationships between the parts in the system observed.

Predictive models - used by the brain to predict and plan for future events and actions.

These models form a progressive series moving toward increasingly abstract relationships. In the human mind, such a series of internal mental models represent the movement from a naive to expert understanding and knowledge of our world.

Modeling in Science

Scientists, applying modern scientific methods of inquiry, use a parallel series of model-building steps to learn about, organize, and explain events in the natural world. Scientists observe phenomena, make descriptive models that define the features and pattern elements, and then try to explain a phenomenon by creating an explanatory model. The organization of information into this explanatory or theoretical model is accomplished by posing hypotheses that define the relationships that are thought to be responsible for the observations. A unique aspect of scientific thinking is that there is a careful testing of the proposed explanatory relationships (hypotheses) by using experimental models to test the explanatory model against evidence collected from the real or natural system. As evidence accumulates to support the hypothesized relationships, a scientific theory is evolved. A theory is a model of current understanding and explanation that results from the interplay of observation, descriptive modeling, explanatory modeling, and experimental evidence.

These models (along with their elements, assumptions, and relationships) are the "content" taught in science education. Scientists use the theoretical models as a starting point to ask questions and explore natural phenomena to a deeper degree. As new scientific information (observations and measurements) are made, the explanatory or theoretical model is either confirmed or changed to accommodate the new information. Thus the process and content of scientific knowledge is intertwined in the enterprise of science.

Modeling in Science Education

Science education is in large part the process of helping students connect their own internal modeling growth or progression of inquiry (which is not innately skeptical) with the scientific progression of inquiry and theoretical models which are derived from the skeptical scientific view. Science education is a matter of teaching both the methods of building, confirming, and altering explanatory models based on evidence and having a working knowledge of the scientific theoretical models themselves. Since the brain's capacity for model-making becomes more sophisticated with cognitive development, science education can be structured to teach the process and content of the scientific knowledge base in a manner appropriate to the learner yet linked to the expertise represented by the scientific community.

It is important that teachers at each grade level see their contribution to the growing foundation of a student's knowledge in this overall context. How each step of this progression of inquiry relates to what precedes and follows your classroom experience is reflected in the following chart:

Progression Of Inquiry		
Grade Level	**Scientific/Critical Thinking**	**Step of Scientific Inquiry**
Kindergarten	Observation	Exploring the parts or elements of a system, the properties of these elements, and the arrangements of system elements into patterns.
Grade 1	Description	Describing and defining system elements, properties, arrangements, and background space. Classifying by characteristics.
Grade 2	Measuring and Description	Measuring elements, properties, arrangements, and background space and learning about cycles and processes of change.
Grade 3	Descriptive Models / Cause and Effect	Developing skepticism of observation and considering cause and effect.
Grade 4	Inferring Observables into Descriptive Models	Beginning to draw general conclusions from diverse information.
Grade 5	Modeling and Verification	Proposing simple linkages of cause and effect.
Grade 6	Testing Explanatory Models with Verification	Constructing models of cause and effect. Forming hypotheses and testing for verification.
Grade 7	Experimental Models and Design	Testing a hypothesis of a proposed model of cause and effect by experiment. Designing and using controls and variables to make conclusions.
Grade 8 and Above	Experimental Models and Design	Inferring unobserved properties from observed properties (observables).

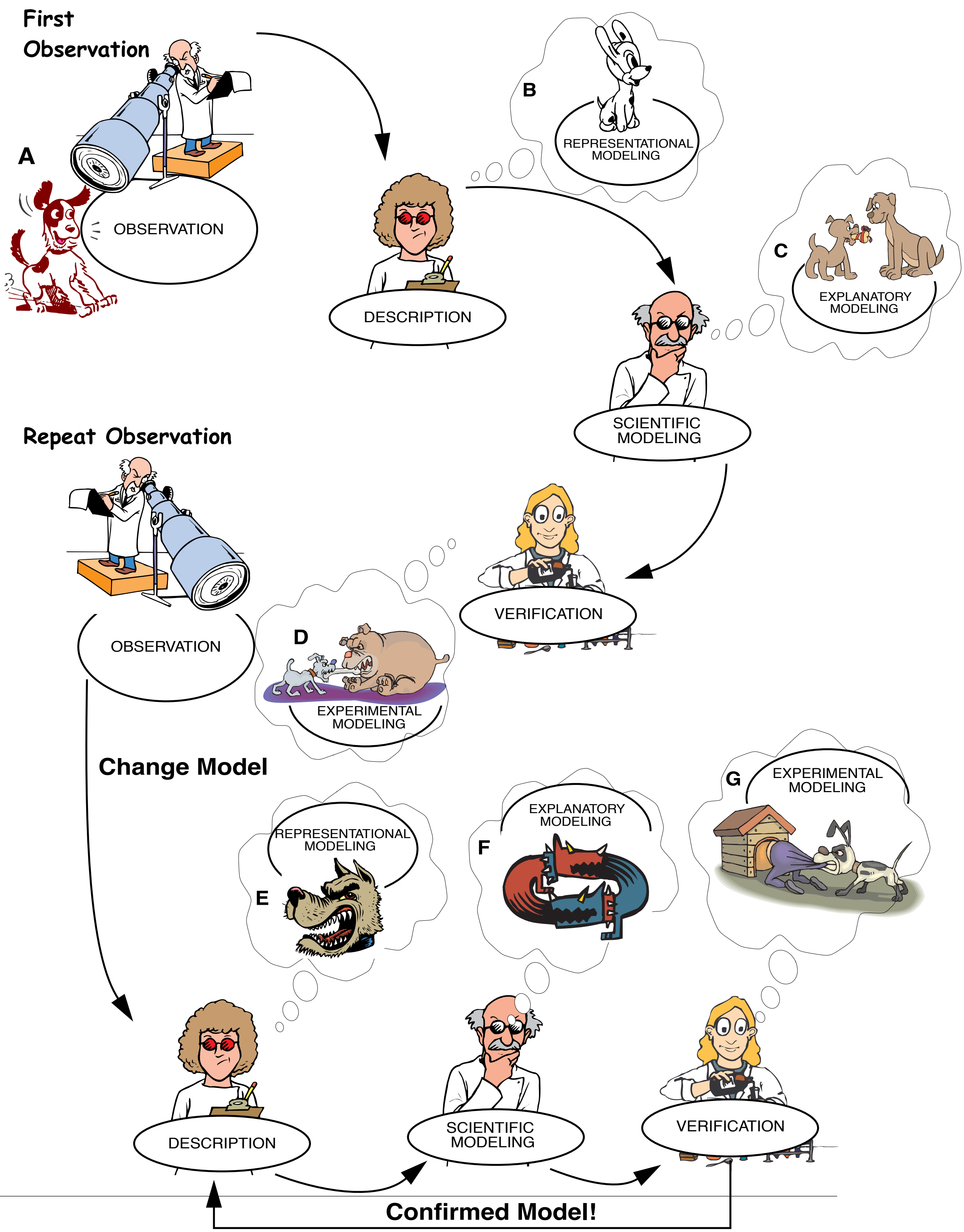
The Scientific Method and Modeling

The SymmetryScience curriculum is focused on the concept that:

Science is a way of looking at the world.

The scientific habit-of-mind or the scientific method of inquiry can be described by these simple steps:

- Observation
- Description
- **Modeling** (the Cause and Effect of the observations)
- **Verification** of the proposed model through **experimental** evidence.
- **Critical analysis** to accomplish each of these and to communicate the results.


First Observation
A
OBSERVATION
DESCRIPTION
B
REPRESENTATIONAL MODELING
C
EXPLANATORY MODELING
SCIENTIFIC MODELING
Repeat Observation
OBSERVATION
VERIFICATION
D
EXPERIMENTAL MODELING
Change Model
REPRESENTATIONAL MODELING
E
F
EXPLANATORY MODELING
G
EXPERIMENTAL MODELING
DESCRIPTION
SCIENTIFIC MODELING
VERIFICATION
Confirmed Model!

Assessment is Fundamental to the SymmetryScience™ Method

Types of Investigation

The SymmetryScience curriculum is a program dedicated to teaching science and using science to teach. We are strongly committed to the scientific principle that successful understanding must be measurable and supported by evidence.

Assessment should be part of the overall process of reaching understanding. In the daily life of the scientist, assessing the evidence is an accepted and welcomed part of the process of collaboration. When students come to view a continuous assessment process as part of the learning process, they will be more likely to engage in intellectual risk-taking. This openness to assessment, criticism, and intellectual risk-taking is the goal of the SymmetryScience program.

There are three broad types of exploratory investigation in scientific work. Each has its own complementary role in structured discovery. The exploratory investigations specifically used in SymmetryScience are as follows:

- Observation or case study
- Calibration or control experiments
- Hypothesis testing or verification explorations

Each of these types of investigation is reflected in the investigation process. Each of these investigation types has a role in a full scientific practice, but the degree of abstract cognitive skill required increases from observation through hypothesis testing. Observation study is frequently the first investigation and is most appropriate for early and middle elementary grades. Calibration and control investigations become necessary as students learn to use laboratory tools and to make accurate measurements. They also form the basis of skeptical inquiry. These types of explorations are added in late elementary and the middle school years. Hypothesis-testing experiments are designed to verify or alter a model system that has been proposed as a cause and effect explanation for a measured phenomenon. These investigations incorporate observation and control experimentation and are the most advanced explorations in scientific practice. Students are gradually introduced from late elementary through the middle school years to these types of investigations and the accompanying assessments.

Informal/Observational Assessment

From kindergarten through ninth grade, the central role of laboratory and field-based exploration in the SymmetryScience curriculum provides daily opportunity to observe students directly. This continuous assessment process is supported by suggestions in the Teacher's Guides that provide guidance to what skills, questions, observations, and relationships should be expected from the students. Teachers' notes provide information about possible errors that might be expected to happen in the experimental experience of the explorations.

Embedded Assessment

The Science Journal is a central part of the assessment process for each activity. Students are given a Science Journal for every part of the SymmetryScience program from first grade through ninth grade. Each Science Journal is designed to act as an open-ended laboratory notebook and supporting interactive text. The journals encourage students to record ideas, questions, library research, models, and experimental data. The Science Journal also provides space and context for analysis and synthesis of data into conclusions.

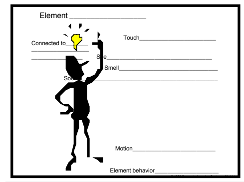
The Science Journals promote respect for the evidence that the students develop. They also promote a sense of real participation in the scientific process by integrating the recording and analysis of data with the content of the subject matter in the same journal. The notebooks can be examined by the teacher and other students, providing an openness to the examination of the data, communication, and evaluation. The journals combine assessment with learning.

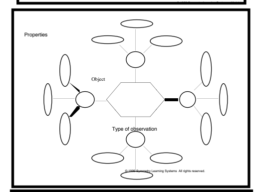
Summative Assessment

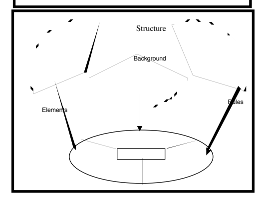
Graphic Analyzers

The SymmetryScience curriculum uses a set of graphic analyzers to apply the Language of Patterns to content throughout the curriculum. This tool gives students and teachers a logical structure from which to build and develop the critical thinking process.

Graphic analyzers are used to establish a common strategy for both the teacher and the student. For the teacher, the analyzer organizes the content and concepts of the lesson to be taught. For the student, the analyzer is used in the construction of knowledge and records the student's progress. The analyzer, therefore, becomes both a learning and assessment tool.







Authentic Assessments

At appropriate points in the Science Journals, certain laboratory experiments are designed to be assessment projects. These experiments are designed to test whether a student who has completed a set of manipulative and analytical skill level investigations will be able to extend their knowledge and thinking to an unfamiliar situation. These practical exploratory exercises are notated in the Teacher's Guides and can be used to evaluate the student's understanding of the concepts and tools, as well as their ability to solve practical open-ended problems. When used with a laboratory report and graphic analyzer, these exercises provide an authentic assessment of the student's understanding.

Components of the SymmetryScience™ Program

The SymmetryScience program is an integrated K-9 science education curriculum. Its major components include:

- **Let's Learn With Science** - grades K-3
- ***SymmetryScience Segments*** - grades 4-9

Accompanying the entire program are "Discovery Centers", Student Science Journals, Parent Notes, Teacher's Guides, and Kinesthetic Explorations.

Let's Learn With Science (K-3)

The **Let's Learn With Science** curriculum is designed to introduce and reinforce the fundamental elements necessary to learn not only science but mathematics, music, and the arts. It lays the foundation for the early learner to develop a comprehensive literacy in science. **Let's Learn With Science** introduces the kindergarten through third grade learner to the vocabulary, basic rules, and simple experiences necessary to gain literacy in the language-of-patterns description, which is the language of science. The program guides a child's natural inquiry by exploring the world around them through activity-based classroom and individual explorations. The core of the curriculum focuses on developing skills in pattern recognition and abstraction of information which are the underlying processes of human brain function. The detection and analysis of patterns are fundamental to the process of describing observations; they form the basis for the development of critical thinking skills in the later years.

Segments Curriculum (4-9)

The **Symmetry Segments** curriculum is designed using structured discovery to build a content and context rich set of practical experiences that allow the maturing student to discover the way the world works by asking real scientific questions. Model building skills are developed from the well-developed pattern recognition skills. The **Segments** curriculum builds on the developing habits of skeptical empiricism by integrating five content areas of science: electromagnetism and light, mechanics and motion, chemical science, biological science, and earth and space sciences. These five areas are arranged to support each other and repeat the fundamental physical, chemical, and biological principles over and over in different contexts as a spiraling curriculum. The natural maturation of the brain during this period allows more abstract generalizations to be derived from specific concrete experiences. The curriculum is flexible and can be used through the ninth grade.

Teacher's Manuals

A Teacher's Manual accompanies each K-3 **Let's Learn With Science** program and the 4-9 **Segments** curriculum. These guides are for use in class preparation and teaching. The guides are designed to mirror the student's Science Journals with the addition of teaching suggestions, connections to other subject areas, science term definitions, and experiment set-up instructions.

Science Journals

Every student in grades 1- 9 works in a Science Journal. These workbooks provide a forum for science discovery, observation, recording, and connections between subject areas. They also present great stories from history which illustrate the fundamental concepts underlying science and our natural world. The Science Journal is used actively by the student and is intended to be both a record of the student's work and also a beginning science library. These workbooks are the "desktop" of the SymmetryScience curriculum. They provide the structure through which to teach and learn science.

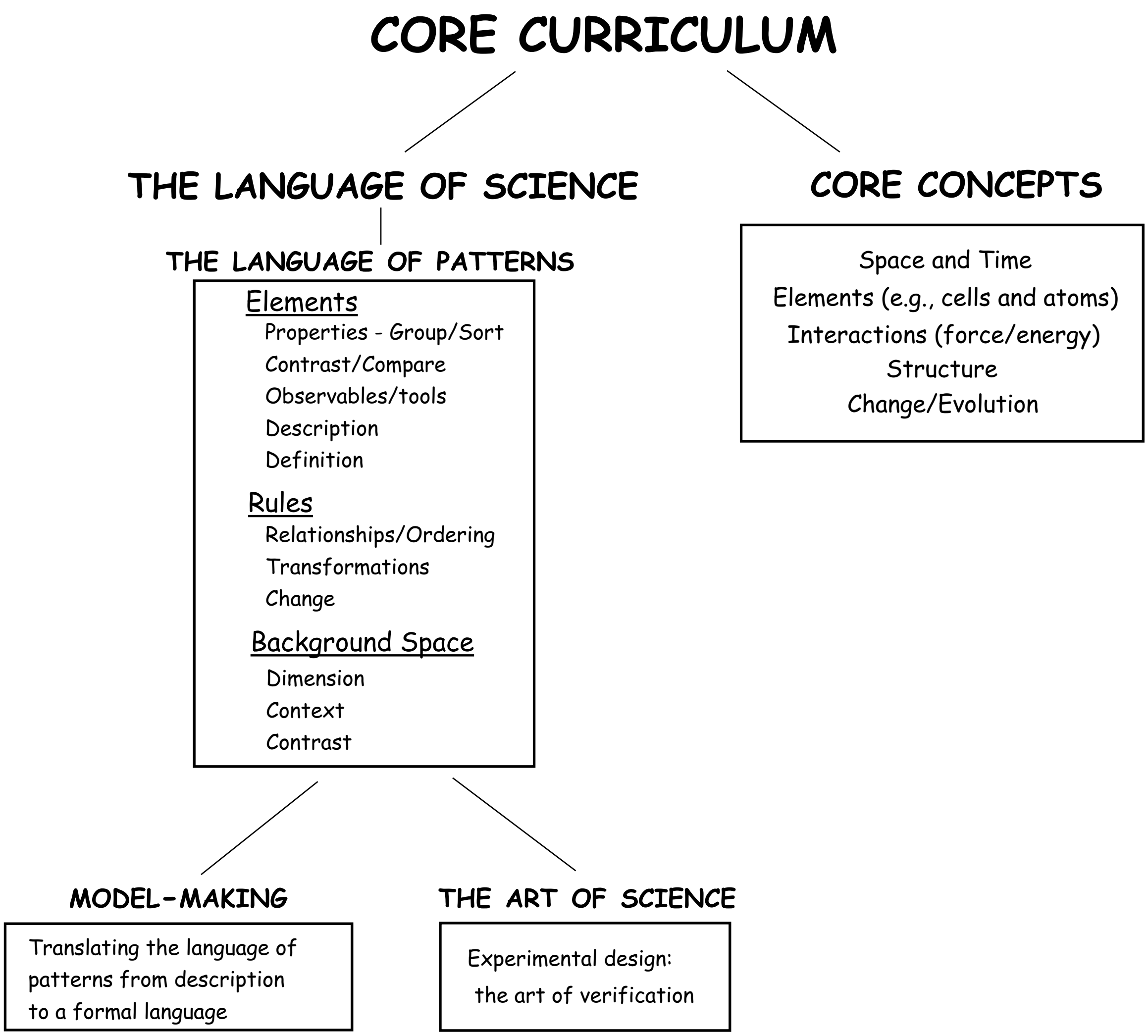
Discovery Centers

The Discovery Centers provide the materials and laboratory equipment needed to perform the experimental investigations. All of the materials required for the activities and experiments are provided (except living organisms and perishable foodstuffs). The inclusion of Discovery Centers is intended to provide teachers "teaching time" with students instead of shopping for and organizing classroom science materials.

The Discovery Center materials are coordinated with **Let's Learn With Science** and the **Symmetry Segments**. Many of the tools and materials used in **Let's Learn With Science** curriculum are reapplied throughout the Segments curriculum. The students benefit from familiarity with the equipment while seeing the experiments in a new and more complex light.

The Core Curriculum

There is an organizational structure to the core concepts in the SymmetryScience curriculum. This core curriculum reflects the requirement that certain concepts must be presented before others can be easily understood. The core curriculum includes the language of science (using the Language of Patterns) and familiarity with certain core concepts that recur in the study of science. The following figures illustrate the core of literacy that comprises the SymmetryScience program. The application of this core curriculum is indicated in the program summary grids that are on the following pages.



The SymmetryScience curriculum guides toward literacy in the following science content areas as defined by the National Science Standards:

Physical Science

Structure of matter

- atomic structure
- chemical elements
- chemical compounds and properties

Interactions between objects (chemistry, physics)

- forces in nature
- forces and motion

Energy flows and changes

- conservation of energy and matter
- statistical behavior in the physical world
- energy transformations and disorder

Biological Science

Physical and chemical nature of life processes

- molecular basis of heredity
- flow of energy and matter in living systems

Biological structure changes through evolution

Language of Science Sequence

The primary goal of **Let's Learn with Science** is a mastery of the Language of Patterns. Children are prepared to observe, classify, sort, describe, define, and find concrete relationships between elements in a system. Experience with the language of science is also gained. Students begin to report their observations and map the system onto simple model systems.

In the **Segments** curriculum, further skill in mapping and model-making is developed. Students develop a set of experiences in designing and implementing experiments with controls, variable adjustment, and hypothesis-testing.

Core Content Sequence

In **Let's Learn with Science**, students perform a variety of physical, biological, and earth and space investigations that tie the learning of the Language of Patterns to the broad ideas in science literacy. Students use properties to group living things, astronomical and weather patterns, and physical events. They then progress to ordering objects based on properties and interaction rules. They learn how to use the senses and tools to measure and confirm pattern features. Thus, the Language of Patterns is used as the grammar, vocabulary, and syntax in a growing library of scientific experience.

In the **Segments** curriculum, the core concepts are also taught first in the context of the Language of Patterns:

- The broad concept that objects in the world interact through a set of rules defined by the concept of force is experienced early.
- Forces (gravity and electric) are introduced as rules that describe the interactions between elements in natural systems.
- Complicated structures are made from smaller particles, i.e., cells to living things, and chemical elements to materials.
- Heat is the back and forth motion of particles.

Using the Language of Patterns to describe the core concepts is a unifying principle of the SymmetryScience curriculum which is progressively expanded into diverse cases that re-emphasize these core ideas over the years. The common language of science is used to explore how weather, planetary motion, simple machines, chemical reactions, and plant and animal diversity can be explored in daily life.

The structure and evolution of the natural world is also described by the Language of Patterns. The concept of structure is straightforward in terms of the Language of Patterns: elements interact according to rules in a specified background space to produce new systems. These systems have their own properties, rules, and background space. Forces can be applied to some aspect of a systems causing it to change or evolve. Change is simply the evolution of a system over time due to some applied interaction. These core concepts can be easily described and communicated with the Language of Patterns. Once a qualitative idea is introduced, many examples of its applications in the natural world are studied with hands-on discovery.

Application of the Language of Patterns to the Core Science Concepts

Language of Patterns

Elements
- Energy-matter
- Subatomic particles
- Atoms and chemical elements
- Biological cells
- Stars and planets

Background (Space-Time)
- Shape and dimension of the universe
- The direction of time (the arrow of time)

Rules (Interactions)
- Matter-energy
- Laws of conservation of energy and matter
- Forces in nature (electric, gravity, nuclear)
- Statistical nature of the universe

A System Is Formed by the Arrangement of Elements in a Background

Structure = Background ↔ Rules ↔ Elements

Systems Change Over Time: This is Evolution

System	**Time**	**Change** and evolution of systems in response to environmental interactions
atomic chemical biological geological astronomical ecological	→	

Let's Learn With Science Program Overview

Let's Learn With Science is an integrated program designed to prepare the K-3 students for a comprehensive literacy in science. The initial focus of **Let's Learn With Science** is on the Language of Patterns. Through the study of patterns, the early learner will begin to think about and describe their natural world. Experience has shown that early exposure to patterns analysis has a profound effect on the student's ability to understand and enjoy arithmetic, language, music, art, and literature. Fundamentally, **Let's Learn With Science** will allow K-3 students to discover the existence of the basic elements and rules in nature. The curriculum is integrated to provide the students with a vocabulary and set of experiences that prepare the child for a more detailed examination of the natural world in the **Segments Curriculum**. There are four progressive sections to **Let's Learn With Science**.

Segments Program Overview

The **Segments Curriculum** uses structured discovery to build a set of practical experiences, rich in content and in full context, which allow the maturing student to discover the way the world works by asking real scientific questions. Model-building skills are developed from the well-developed pattern recognition skills. The **Segments Curriculum** builds on the developing habits of skeptical empiricism by integrating four content areas of science. These four areas are arranged to support each other and repeat the fundamental physical, chemical, and biological principles over and over in different contexts as a spiraling curriculum. The natural maturation of the brain during this period allows more abstract generalizations to be derived from specific concrete experiences.

The students are constantly challenged through the use of an integrated series of portfolio-assessment Science Journals to construct and perform many of the same explorations undertaken by the master scientists themselves: Galileo, Faraday, Newton, Volta, Carlisle, Dalton, and Pasteur, just to name a few. Every **Segment** is built around embedded stories dramatizing the personalities and the experiences that led to the range of scientific discovery that comprises the tradition of modern science. There Segments are flexibly arranged so that the content of each is explored and related to one another, as well as to social, historical, and technological contexts in which the scientific inquiries were made. The curriculum is a spiraling, modular program in which the elementary concepts of the natural world are presented first.

Let's Learn With Science

Grade Level	Synopsis
K	**Let's Learn With Science - Kindergarten. Marty's Miraculous Monday.** Meet Marty...He is discovering that his world is filled with all sorts of wonderful things. Come along with him as he meets a new friend, Mary who shows him how the properties of color, shape, texture, rhythm, sound, and motion can make amazing patterns, each with its own special rule. But the most remarkable thing that Mary shows Marty is that patterns always happen in a special space or background. And Marty discovers that the background is often just as important as the pieces of the pattern itself! Every day of one wonderful week, Mary shows Marty a new marvel. Before long he is becoming an expert at recognizing and describing all sorts of patterns and connections in his world. As the week comes to its end, Marty worries that all of his new knowledge will also end. Mary, however, helps him discover how this new awareness of patterns can be used over and over again to discover new lands of knowledge. This kindergarten curriculum is a story-based program which focuses on recognizing, sorting, and grouping properties of objects. Understanding that patterns are composed of both background and elements, which repeat following certain rules, is a major focus of this program. The students explore everyday patterns in the context of color, texture, rhythm, sounds, heartbeats, rocks, animals, plants, letters, numbers, and their personal world. The classification of materials according to magnetic properties extends the types of observations that students make. These concepts relate to organizing information and building knowledge about the natural world by recognizing the elements in the world, arranging the elements according to certain rules, and classifying the elements by their properties against a background space. The year long program ends with a school wide celebration - the Pattern Pageant.
1	**Let's Learn With Science - Level 1.** Mary and Marty become pen pals and learn about Ben Franklin and Polly Stevenson. Throughout the first grade curriculum the Language of Patterns is used in an exploration of the natural world. The primary objective of the previous year's curriculum was for the early learner to become familiar with the structure of patterns and appreciate that patterns could be explored in a systematic way. The students were introduced to the ideas and vocabulary of the core critical-thinking language of SymmetryScience, the Language of Patterns. In **Let's Learn With Science - Level 1**, this introduction is formalized by helping each student learn how to structure an observation using the Language of Patterns and a series of graphical organizers. Now, the students will describe their experiences in the natural world by applying their knowledge of basic patterns. The students learn to use properties, grouping, sorting, and patterning as a scientific tool to classify things by actively exploring and experimenting with several aspects of their own world: the human senses and the physical properties of things, the properties of plants and animals, and the properties of rocks and soil.

Let's Learn With Science

Grade Level	Synopsis
2	**Let's Learn With Science - Level 2.** The second year curriculum is presented in three Units. In Unit 1, the Patterns of Heredity, the students are introduced to the principles of heredity and biology and are introduced to their classmates by learning the Language of Patterns as they measure and describe themselves, their family, and their classmates. This introductory unit uses scientific process skill to explore the observable result of heredity and environment, teaching biology, social science, and measurement while using the common context of the Language of Patterns. In Unit 2, The Patterns of the Weather, students explore, measure, describe, predict, and model the weather using the systematic approach of the Language of Patterns. In this integrated unit, students discover the elements of the weather (temperature, wind, humidity, clouds, and barometric pressure). They learn how the water cycle and weather are related and build weather measuring instruments to describe and predict the weather and weather patterns; each student takes a turn at being the class weather forecaster. In Unit 3, The Patterns of Motion, the concepts of describing motion in terms of properties, position, and direction are introduced. Students use a "story" approach and the Language of Patterns to begin to speak a fundamental language of physical science - mechanics. Using the playground and in-class laboratory experiments, students discover how to measure and describe motion, recognize and characterize forces, and see that objects sometimes can be balanced.
3	**Let's Learn With Science - Level 3.** The third grade curriculum is also presented in three units. Unit 1 is Exploring with Science: Slime, Spots, and Models. This unit reviews and extends the application of the Language of Patterns to exploring complicated phenomena scientifically. The class starts the year by making slime and then analyzing this experience to learn first-hand how a scientist observes, describes, and models a chemical system as a way to understand the properties observed. Then these process skills are extended, using chromatography to analyze a spot of ink and food coloring as chemical systems. In Unit 2, Patterns of Light, Heat, and Shadow, students explore how light is produced, its properties, spectrum and its refraction, reflection, and scattering by matter. Then they explore shadows and experiment to discover the relationships that govern shadow quality, shape, and size. Finally, the concept of transformations of energy are introduced by exploring the relationship between light and heating of the earth and objects. In Unit 3, Patterns in the Sky, students use the Language of Patterns and progression of Inquiry to explore the relationship of the sky and the earth. Observations and measurements of daytime properties are explored by experimenting with photocells and thermometers. Students construct models to explain the observation of the motion of the sun, the phases of the moon, and appearance of the stars and planets. This unit builds upon the principles of light, heat, and shadows explored in LLWS-3 Unit 2.

Physical Science: Electricity, Light, and Magnetism

Grade Level	Segment Synopsis
4-5	**The Electric World:** Students discover and measure the behavior of the electric charge and force using static electricity to light fluorescent bulbs, and to attract wood and metal. A sensitive force balance of their own making is also built. They discover that like charges repel and unlike charges attract using rods made from different materials. They build an electroscope to measure the electric force; they explore how materials like quartz and metals can be used to make batteries and sparks. These explorations conclude with discovering how simple circuits can power bulbs and buzzers.
4-5	**Magnets:** The properties and rules of magnetism are discovered by classifying magnetic properties of common materials, using force balances and magnets to describe the strength and penetration of the magnetic field through materials and over distance. Using magnets, the laws of attraction and repulsion are found. The fact that every magnet has a north and south pole is discovered. Students measure magnetic force by building a simple magnetometer, designing magnetic motors, and experimenting with magnetic levitation. Using magnets and iron filings, magnetic lines of force are mapped and related to the Earth's magnetic field and the use of a compass.
5-7	**Electromagnetism (unpublished):** The relationship between magnetism and electricity is explored by showing that flowing current orients a compass needle and that these magnetic field lines can be shown with iron filings. The use of these effects to measure electricity is explored by building a galvanometer. After building an electromagnet, magnetic field lines are mapped; an electromagnetic motor and a solenoid are studied to explore work and motion. The Faraday effect is discovered and used to build an electrical generator. Induction is explored by experimenting with two wound coils, and the transformer is explored making sparks, radio waves, and light from electric current and an electromagnetic coil.
6-8	**Sparks to Circuits:** Similar to the structure of The Electric World, this Segment is designed for older students and can be used to review and extend experience with electricity. In addition to the experimental experiences listed above in the Electric World, students learn how static charge can flow down a wire and that there is a difference between induction and conduction. The flow of charge in series, parallel, and logic circuits is explored along with Ohm's Law. This Segment prepares students to use modeling in hypothesis testing and experimental design by introducing the ideas of model-making.
6-8	**Light and Color (unpublished):** The relationship between electromagnetism and light is rediscovered using a coil to produce electromagnetic radiation. The interaction of light with matter is explored using mirrors and lenses. Working with filters, prisms, lenses, mirrors, and a smoke box, the properties of light when it is reflected, refracted, absorbed, and scattered are discovered. Image formation and illusions are experienced by making a kaleidoscope, a wide angle mirror, and a floating flower pot. The relationship between color and the electromagnetic spectrum is explored with filters and pigments, as well as with building color wheels, projectors, and simple spectroscopes.

Physical Science: Mechanics And Motion

Grade Level	Segment Synopsis
4-5	**Heat (unpublished):** Using thermometers, heat sources, and ice baths, the movement of heat energy in materials is explored. Heating and cooling is discovered to be related to the changes in state and properties of materials such as water, rubbing alcohol, and oil. Using Kidolecules™ and the Kinesthetic Exercises, a physical model of heat as "jiggly" motion is introduced. These exercises are compared to the expansion of metals, gases, and liquids with heating and while measuring temperature. Experience with making thermometers and using them to measure heating and cooling effects are performed. The properties of different materials as thermal insulators and conductors are explored using thermometers, the sense of touch, and heat sources. These properties are related to the model of matter and internal motion already developed.
5-7	**The World of Gravity:** The force of gravity on matter is explored by experimenting with the sensation of weight in the air and in a water tank. The relationship between measured weight and the force of gravity is explored with spring scales. The discovery of an anti-gravity force that can be felt in the water tank, measured on the spring scale, and used to make an anti-gravity rocket leads to a series of experiments with the buoyant force. The effect of the mixed forces of gravity and the buoyant force are measured by building equal arm balances and exploring the relationship between mass, volume, and floating or sinking. The problem that Archimedes solved in ancient Greece is explored; by building crowns made from "silver" and "gold" mixtures; the ideas of density and the volume of displacement are discovered. The behavior of objects affected by a gravity force and a buoyant force are explored using hydrometers, building ship hulls, and floating ice cubes in mixtures of liquids.
6-8	**Energy, Work, and Machines (unpublished):** The nature of forces to interact with matter and to cause movement are related to experiments done with gravity, electricity, and magnetism. A variety of machines that convert energy from one form to another are built in order that energy transformations can be experienced. The concept of energy as something that is exchanged in a system is discovered by experimenting with energy stored (potential) in the gravitational and electric fields and by experimenting with the energy of motion (kinetic) that is present as an object moves on a spring or a pendulum. The relationships between force, work, power, and energy are experienced by building machines with wheels, levers, inclined planes, and pulleys and measuring how they change the direction and application of force but do not change the total energy.
6-8	**The Atmosphere:** Discovering the properties of air is treated as a problem in learning about the background of a very familiar system. Students relate many of their earlier experiences with floating and sinking, density, heat, chemical analysis, properties of force, energy, etc., as they discover and prove that air has weight, takes up space, and exerts pressure. They will construct barometers to measure air pressure and model the behavior of air using Kinesthetic Exercise. They discover that air has chemical properties as well as physical properties by experimenting with oxygen, water vapor, and carbon dioxide.

Chemistry

Grade Level	Segment Synopsis
6-8	**Atoms and Elements:** The vocabulary and concepts of atoms, elements, bonds, chemical properties, chemical changes, and physical changes are initially introduced. Then the scientific thinking and experimental evidence that underlie the particulate model of matter, which is the theoretical basis of modern chemistry, are introduced. The fundamental views of the particulate or atomic theory of matter are progressively developed. The Tools of the Chemist Unit introduces the use of volume, mass, and temperature measurements as the central tools needed to explore and infer chemical properties and change. Students learn to use and apply graduated cylinders, balances, and temperature measurements to the problem of physical characterization of substances. Each experiment in this unit uses the vocabulary introduced in the initial unit to teach both chemical principles and the experimental methods of scientific inquiry. The Structure of Matter Unit is an explanation of the scientific evidence that supports the atomic theory of matter. Students use the tools and methods of scientific inquiry to generate and evaluate experimental evidence that supports the theoretical arguments of the atomic theory. The systems of diffusion, surface tension, and solutions are used to test the inferred relationships (hypotheses) of the particulate model of matter.
6-8	**Chemical Reactions and Compounds (unpublished):** The patterns of chemical reactions and the rules that allow reactions to be predicted are explored in these experiments. First, students discover that the total mass is preserved in chemical reactions and that this observation is codified as the law of conservation of mass. Experiments exploring acid-base reactions, color reactions, and exothermic and endothermic processes are used to discover that substances can often be placed into groups based on reaction patterns. This discovery leads to an introduction to analytical chemistry where reaction patterns can be used to identify unfamiliar materials. Experiments are performed in which temperature, acidity, light, and catalysts are varied to have students discover that reaction rates can be influenced by the environment.
6-8	**The Mystery of the Electric Lemon:** The experiments of the two scientists Galvani and Volta are explored while investigating the question of animism and electricity. This Segment applies knowledge in electricity, chemistry, and the scientific method to investigate the claim that an electrochemical cell made from copper, zinc, and a lemon draws energy from the biology of the lemon. This guided research program uses control experiments, modeling, and hypothesis-testing along with analytical chemical tools and electrical measurements with voltmeters to prove that the energy comes from the metals and not from the "living lemon".
7-9	**Electrochemistry (unpublished):** Electrochemical cells are built from a variety of electrode metals to establish an electromotive series as a way of classifying chemical materials. Electrolysis is used to break water into hydrogen and oxygen; these elements are analyzed using tests developed in previous segments. How electrolysis can produce other chemical compounds is explored by the electrolysis of salt water to produce chlorine and bleach. The color reactions of bleach and the germicidal properties of chlorine are discovered. Students build electroplating systems. Electrochemical corrosion is experienced and experiments are performed to explore factors influencing corrosion prevention strategies. Finally, the role of electrochemistry in bioenergetics, food preservation, and defense against bacteria in animal and plant systems is discovered.

Biological Science

Grade Level	Segment Synopsis
4-5	**The Patterns of Life (unpublished):** That all organisms share the same needs but have diverse solutions is discovered by growing colonies of plants and molds. The patterns of life cycles, energy and matter cycles, and response and impact on the local environment are explored and described in terms of elements, ordering rules, and requirements in the background space. Simple chemical and physical measurements of water, air, and energy needs are compared between living systems. The effect of temperature, light, and nutrients on growth is explored. Simple structural analysis is begun, such as how stems and roots work together to support leaves. The effects of growth on the acidity of a local environment is measured.
5-6	**The Elements of Life (unpublished):** The cell as the fundamental building block of living organisms is introduced. Cells are modeled and are studied in terms of their energy use and waste production, reproduction, growth, motion, and defense mechanisms. Many of the same questions that had been raised in The Patterns of Life are revisited but at a more sophisticated level. The question, What is alive? is examined. Specialization of cells and the cellular basis of heredity are introduced by investigating growth in the classroom.
6-7	**The Microscope:** The use and care of the microscope are taught by considering the microscope as a tool that extends human senses. Although the microscope is traditionally considered a "biologist's" tool, the principles of physics and engineering design that make the microscope so valuable in biology are presented first. A review of the optical principles that allow lenses to magnify and form images is presented in a series of experiments that also teach the scientific method, including control experiments and dependent and independent variables. Then, the application of the microscope, primarily in biology, is explored. Samples from the biological world are explored as students gain experience with the compound microscope.
6-8	**Plants (unpublished):** How plants solve the fundamental problems of biology is explored by exploring the structure and function of roots, stems, leaves, flowers, and seeds. The influence of light on the direction of stem growth, pigmentation and photosynthesis, and transpiration are all discovered in a series of investigations. The role of the stem and the anatomy of the fibrovascular structures are explored and deduced by studying the transport of liquids and solids. Leaves are examined to discover their anatomy and physiology. The interaction of light, photosynthesis, oxygen, carbon dioxide, and water usage in the leaf are connected by measuring pigmentation, carbon dioxide, and oxygen production and consumption, and starch production and use.
7-9	**Animals (unpublished):** This Segment explores the energy needs and organization of animals. The classification problem of whether yeasts are animals or plants is solved by considering biochemical and anatomical attributes. The explorations examine the digestive, respiratory, and circulatory systems, and the muscles and brain. Animal life cycles, asexual and sexual reproduction are introduced along with reproduction and growth and development of animals

LEVEL	SYMMETRY SCIENCE TEACHING PROGRAM			
Entry	LET'S LEARN WITH SCIENCE - KINDERGARTEN			
	Sorting and Grouping	Patterns of the Body	Pattern Making	
One	LET'S LEARN WITH SCIENCE - LEVEL 1			
	The Human Senses and Physical Properties	The Properties of Plants and Animals	The Properties of Rocks and Soil	
Two	LET'S LEARN WITH SCIENCE - LEVEL 2			
	The Patterns of Heredity	The Patterns of the Weather	Patterns of Motion	
Three	LET'S LEARN WITH SCIENCE - LEVEL 3			
	Exploring with Science: Slime, Spots, and Models	Patterns of Light, Heat, and Shadow	Patterns in the Sky	
	SEGMENTS CURRICULUM STRANDS			
	PHYSICS I	PHYSICS II	CHEMICAL SCIENCE	BIOLOGICAL SCIENCE
4 - 5	The Electric World	Heat		The Patterns of Life
	Magnets			
5 - 7	Electro-magnetism	The World of Gravity		The Elements of Life
6 - 8	Sparks to Circuits	Energy, Work, and Machines	Atoms and Elements	The Microscope
	Light and Color	The Atmosphere	Chemical Reactions and Compounds	
			Mystery of the Electric Lemon	
7-8				Plants
				Animals
7-9			Electro-chemistry	