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ABSTRACT

Background information and exemplary units for teaching science in Georgia's middle school grades are provided. Discussed in the first section are: (1) the rationale for including science in middle school grades, focusing on science/society/technology, science/social issues, scientific reasoning, and scientific literacy; (2) role of science instruction, including curricular ramifications due to cognitive development and physical/social-emotional development; (3) development characteristics of middle grades students; (4) curriculum planning, including needs assessment, unit selection, specifications of goals/objectives, implementation activities, and evaluation; and (5) inquiry instructional strategies designed to foster problem solving skills. Three units, differing in style and format, are provided in the second section. Each unit uses three elements of inquiry discussed in the previous section (rationale, discovery, experimental). The units are useful if teachers are inclined to adopt them intact; however, their primary function is to serve as models for designing other units. Topics considered in the units include energy; physical and chemical changes; and molecular transport and exchange of gases within the biosphere. A list of essential science skills is provided in an appendix. (Author/JN)

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Foreword

The Georgia Department of Education has produced *Teaching Middle Grades Science* as part of its effort to provide guidance for instructional development in all curriculum areas. This guide is specifically designed to fit into the continuum which begins with experiential learning in the early grades and ends with content concentration in the secondary schools. Its unit teaching approach is an excellent blend of process and content.

I am confident that this document will be a useful resource to curriculum leaders and instructional personnel in Georgia schools.

Charles McDaniel
State Superintendent of Schools

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Preface

Science in the middle grades must carefully link the generalized experiences of preschool and elementary school years with the specialized learning experiences of the high school science studies.

The preschool science experiences of youngsters are almost totally individualized and primarily unstructured. The elementary school science experiences are characterized by observation, description and cataloguing of the natural and technical environments, along with the acquisition of skills of information gathering and synthesis. The high school years are characterized by special studies in the natural phenomena of life, earth, space, structure and behavior of matter and the associated natural laws governing behavior in these areas. The high school carefully categorizes natural phenomena and develops an appreciation for structured problems (experiments) related to them. The elementary school promotes observation, cataloguing and the combination of these elements.

It is the role of the middle school to build problem solving experiences from the generalized lore assimilated in the elementary school. Problem solving skills attained during these years are then directly applicable to the laboratory and field studies of the specialized realms of chemistry, physics, geology, biology and other categories of scientific pursuit in the high school. They are equally applicable to the common problems of competing in economic enterprise, vocational choices or socialization.

Thus the middle grades science program should stress problem solving in a unit format selected carefully from the natural and technical environments familiar to the learner.

This guide has been developed to help middle grades teachers in Georgia schools structure meaningful units of instruction for the unique and transitional students they serve.

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Science in Georgia's Middle Grades

A growing dissatisfaction with the organization and content of the junior high school has led to a minor revolution in the education of early adolescents. The junior high school started out with the admirable aims of providing a transition between elementary and high school and a bridge between childhood and adolescence. Despite these goals, many educators, community leaders and junior high students have become increasingly aware of the institution's shortcomings in recent years. This dissatisfaction has led to an upsurge of the middle school. In 1967 Cuff found only 500 middle schools nationwide, while Brooks identified more than 4,000 throughout the United States in 1978. Georgia, too, found itself in the midst of this change to middle school. The number of middle schools in the state increased from 94 in 1965 to 252 in 1981.

The growth of the middle school has not been limited to a change of name from junior high to middle school. Changes in the way teachers relate to students as well as the teaching methods and techniques used by teachers have been the primary goals of middle school proponents. The following draft taken from *The Essential Middle School* (Wiles and Bondi, 1981) illustrates the transitory nature of the middle school and the roles this institution should serve when compared to elementary or secondary schools. These roles are different primarily because the student populations of the various schools are different in terms of physical, socio-emotional and intellectual abilities.

Figure 1

Relative Roles of Elementary, Middle and Senior High Schools from *The Essential Middle School*, Wiles and Bondi, 1981.

	Elementary	**Middle**	**High**
Teacher-student relationship	Parental	Advisor	Instructor
Teacher organization	Self-contained	Interdisciplinary team	Department
Curricular emphasis	Skills	Exploration	Depth
Schedule	Self-contained	Block	Periods
Instruction	Teacher-directed	Balance	Student-directed
Student grouping	Chronological	Multiage developmental	Subject
Building plan	Classroom areas	Team areas	Department areas
Psychomotor development	Skills and games	Skills and intramurals	Skills and interscholastics
Media use	Classroom groups	Balance	Individual study
Guidance	Diagnostic development	Teacher helper	Career-vocational
Teacher preparation	Child-oriented generalist	Flexible resource	Disciplines specialist

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Science for middle school youth has not developed quite so quickly. While the National Science Foundation has put increased emphasis on early adolescence as a targeted funding group, little change in classroom practice has been evidenced because of this emphasis. Certainly, more science educators and classroom teachers talk about science appropriate to this level, but talk appears to have outdistanced action in this regard. Little suitable curriculum material and teaching methodology has appeared in the middle school science classroom.

The interest of the Georgia Department of Education lies particularly in the area of science for young learners. This guide is designed for use in grades five through eight. Schools may be organized in many different ways, but if any of these grades are represented, this guide should be useful.

Rationale

Why should science be a regular curricular subject in the middle grades? What societal or individual needs does it fill? What are the major goals of science education at this level? All of these are important questions, answers to which must be outlined. Certainly science as a regular part of the middle grades curriculum has become tradition in Georgia schools. Additionally it is required in standards. But are there reasons for the inclusion of science other than mere tradition or because "we have to"?

Science, Society and Technology

One most important need fulfilled by studying science is a continued update on scientific and technological advances which affect our daily lives. We live in an age of tremendous change, much of which is brought about by pure or applied scientific technological developments. The preliminary success of the Space Shuttle and the overall accomplishment of the space program is one such example of science and technology producing change which affects each of us. The practical products generated as a spinoff of this program and the scientific knowledge gained of the moon, our solar system and even the earth itself have enriched the lives of all Americans. Because of these programs satellite communications using television and telephone have become commonplace and accepted modes of exchanging information.

Other advances are also occurring. The scientific development of miniaturized computer chips which perform the function of large numbers of wires and circuits is causing great change. This development has reduced manufacturing costs so greatly that schools, small businesses and homes are or will be using small minicomputers for tasks unthought of even a short time ago. Alfred Bork, one of the prime proponents of computer-based education, agrees.

> "We are at the onset of a major revolution in education, a revolution unparalleled since the invention of the printing press. The computer will be the instrument of this revolution. While we are at the very beginning—the computer as a learning device in current classes is, compared with all other learning modes, almost nonexistent—the pace will pick up rapidly over the next 15 years. By the year 2000 the **major** way of learning at all levels, and in almost all subject areas, will be through the interactive use of computers." (Bork, 1979)

How this will affect learning or life in general is uncertain, but that it will affect the way we live and especially the careers we choose seems assured. Science at all grade levels needs to keep students updated and aware of these potential changes.

Science and Social Issues

Scientific progress also produces important issues that should concern everyone. Various environmental questions are at the heart of these issues. The present battle being waged over the safety of nuclear power generators is one specific instance of this process. On the one hand, there is an obvious need for more and cheaper electrical energy, especially with the scarcity and rapidly increasing cost of fossil fuels. On the other, nuclear castatrophe must be averted. While the resolution of this dilemma will not be simple, the

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involvement of an educated, rational public is most important for the future of the American political process.

Air and water pollution and genetic engineering are all issues that, like nuclear energy, have a strong science component but cannot be decided on scientific grounds alone. The resolution of these issues must be based on the prevailing values of American society. Science education has a responsibility to insure that these values are built upon a sound understanding of the scientific principles involved.

Middle school is a unique place to begin to delve more deeply into some of these issues. Many students during this time are just beginning to show an awakening social conscience. The boundaries of the world are no longer just family, a few friends and the school. The world is taking on new meaning. Because this new understanding of the world is not yet mature and well formed, it is ripe for appropriate input from science. Thus, as values develop and change in an individual student, a reasonable base of information is available to influence those values if science education has done its job.

The Promotion of Scientific Reasoning

Another important rationale for science involves the development of generalizable intellectual capacities which will help the individuals in making adult decisions. While science instruction cannot take on the entire responsibility for intellectual development, it certainly has a role. Scientific thinking is a unique way of looking at the world. This way of thinking emphasizes rational data collection which, when completed, will yield generalizable results. Commonly the procedure begins with the statement of a problem or the asking of a question. To solve the problem one must identify important variables and control them through an experimental design which will allow important generalizations to be drawn. While this inquiry process can be complicated, it is appropriate for middle school students in its simpler forms.

Most important for educators and the public to understand is that this way of thinking is the hallmark of science. Without science as a regular classroom subject, many adults would not have experience with this inquiry strategy. Yet this strategy can be a useful one even in such mundane tasks as choosing an appropriate brand of corn flakes in the supermarket or buying a major kitchen appliance.

Scientific Literacy

The concept of scientific literacy has been embraced as a major overriding goal of science education and it deserves some review here. In general, the scientifically literate person is one who has "the necessary intellectual resources, values, attitudes and inquiry skills to promote this development as a rational human being" (Carin and Sund, 1980). Pella, O'Hearn and Gale (1966) defined the scientifically literate person as having an understanding of

the interrelationships of science and society;

the ethics that control the scientists' work;

the nature of science;

the basic concepts of science;

the difference between science and technology;

the interrelationships of science and the humanities.

Carin and Sund (1980) add the following. "The scientifically literate person

understands that the generation of scientific knowledge depends upon the inquiry process and upon conceptual theories;

distinguishes between scientific evidence and personal opinion;

has a richer and more exciting view of the world as a result of his science education."

Thus, the scientifically literate individual is a person able to use rational thought processes in the many situations demanded by our technology society. Science education must continually strive to achieve this goal. The beginnings of education toward this end must come **no later** than middle school.

Role

What is the role of science instruction in the middle grades? Given the need for developing a scientifically literate populace as well as the developmental limitations of early adolescent children, a general model of the role of middle grades science can be drawn. The central theme in this model must be the individual, unique and transitional. It is the nature of youngsters at this age which makes the middle grades unique. Thus it must be this singular nature which acts as the foundation for science education during these years.

Curricular Ramifications Due to Cognitive Development

It is not enough to say that most middle grades children are not formal operational. What effect does this have on what our students can learn? What does research tell use about techniques to use? What are some potentially promising directions?

Concrete and Formal Concepts

Lawson and Renner (1975) operationally defined concrete and formal science concepts. They were interested in determining whether formal and concrete students could learn different kinds of science content equally well. Those concepts whose meaning is derived from theoretical models of science and not from concrete observations or objects were termed formal. Examples include nuclear fission, the atomic model and density. Each of these concepts must be understood "in terms of other concepts, functional relationships, inferences, postulates and/or idealized models" (Karplus, *et al*, 1977). Concrete concepts are those which "can readily be understood in terms of familiar actions, observations and examples" (Karplus, *et al*, 1977). Examples of concrete science concepts include the cell, mixture and life cycle (all can be physically observed).

Lawson and Renner found that formal students performed considerably higher than concrete students. Especially interesting, however, is the fact that almost no concrete students showed mastery of formal concepts. While formal students did master some formal concepts, they performed much higher on the concrete concepts.

Following up on these results Cantu and Herron (1978) explored the relative efficiency of using illustration, diagrams and models to teach formal and concrete students. They concluded that no matter what kind of concepts were being taught, formal students achieved greater than concrete students, concrete "students did not learn any of the formal concepts very well" and concrete students did learn concrete concepts provided formal reasoning was not part of the teaching strategy used. Similarly Goodstein and Howe (1978) attempted to show that concrete models and exemplars will encourage better understanding by both concrete and formal learners. Their results indicated that concrete "students did not profit from the use of concrete models and exemplars" although formal students did profit from their use.

Even though these studies were conducted with high school students and high school subject matter, it can be inferred that similar results would occur with children, 9-13. Certainly the data from these studies implies that science teachers at all grade levels should be taking a long hard look at their course content. If many of our students are not formal operational even by grade 12, and if concrete operational students do not learn formal concepts, then this leaves middle school teachers with no alternatives. They should concentrate on concrete concepts instead of the more abstract ideas of science and they should attempt to develop teaching procedures that use concrete examples, models and other materials as much as possible. Clearly most teachers would agree that a quick perusal of many texts for grades 4-8 (especially seven and eight) shows more abstractions and less materials-based science than this research indicates is appropriate.

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Teaching and Development

Should teachers reduce the complexity of science content without attempting concomitantly to raise the level of thought among students? Hopefully, not. We must redouble efforts to identify successful teaching strategies and to apply them in the classroom. While the research on teaching strategies is mixed, it appears that certain kinds of variables offer hope.

In an excellent review of recent literature Levine and Linn (1977) list several variables relevant to scientific or formal reasoning. Among these are the number of variables in a given problem, the student's familiarity with the variables, the amount and quality of school experience, the strategy for task completion and the students' problem organization skills. All of the above factors can be controlled by the middle school teacher. By organizing numerous experiences with experimental variables and situations with which children are familiar and by carefully controlling the number and complexity of the variables being considered, the teacher can begin to shape the experimental background of students. It also appears advantageous to present useful learning strategies when appropriate, both those that help solve types of problems (*e.g.*, an emphasis on a "fair" experiment) and those that help organize and clarify information (use of written records and charts).

Levin and Linn gleaned these generalizations from numerous individual and independent studies. None of these was greatly successful at improving the level of thought as measured by transfer of abilities on highly related tasks. But most used only short term training (from four short to 12 40-minute sessions). While long term effects of such procedures can only be conjecture at this time, these methods do offer good possibilities. It is these procedures to which Karplus, *et al*, (1977) refer when they say

> "... teaching can have some influence on the development of reasoning by students in the age range being tested here (13-15 year olds). Applying proportional or control of variables reasoning is not the result of a process inclusively internal to the young people." (p. 416)

Cognitive Development Summary

Thus the research results point to many conclusions for middle school teachers. First, it is obvious (as many experienced teachers have known for years) that most children of ages 9-14 are not formal operational and that no matter how we teach, the students will have great difficulty comprehending abstract scientific concepts. Second, we should review our curriculum topics and cull out the unnecessary abstract concepts. Contrary to high school science, where formal concepts are intrinsic to chemistry and physics instruction, there is no real curricular necessity for teaching abstractions to children in grades 4-8. Enough important concrete concepts are certainly available. Lastly, all the data is still not available on formal education's ability to influence the thinking abilities of students. While short term training has not proven very effective, the effect of long term intervention has yet to be fully measured.

The Potential for Science Process Skills

One final note of importance to science teachers should be made. Over the past 20 years or so, much emphasis has been placed on the science process skills. This dimension arose out of the curriculum development projects of the 50s and 60s. Of enormous importance is the similarity between the integrated process skills and many of Piaget's logical abilities, such as identifying and controllng variables, hypothesizing, application of proportional reasoning in data interpretation activities and many others.

Padilla, *et al*, (1981) in a correlational study investigated this relationship by testing almost 500 Georgia middle and secondary students with process skills and formal thinking measures. Results showed a very strong relationship between the two sets of abilities (r = .73) indicating that training with process skills may enhance logical thinking abilities. Future research may show this to be so. For now the classroom teacher must use the tentative results to guide teaching strategies. More work with process skill activities, especially those stressing a fair experiment, is needed, beginning in middle schools. The major point to be considered is that many of the process skill abilities are developmental in nature and thus will not and usually cannot be learned over a short period of time.

Ramifications Due to Physical and Social-Emotional Development

Physical and social-emotional changes during the middle school years also dictate certain aspects of the curriculum. Most important is that middle school science teachers be aware that the behavior of students of this age is often a **result** of the many changes they are undergoing. The teacher who knows this is able to change teaching strategy in order to adopt and a... unt for difficulties students may be having. What specific ramifications follow from the physical and social-emotional changes? A few are discussed below.

Classroom Activity

Because of physical changes in students, many have great difficulty sitting still and concentrating over a long period of time. It just is not physically possible to do this. Thus work in the science classroom must be geared to the true physical attention span of individuals. In a science class period the teacher might plan one or two changes of activity, each change helping the students refocus their physical and mental attention.

In addition, laboratory activity important for developing the cognitive experience necessary for teaching many science concepts can also be critical in using the typically high energy level of children this age. During this type of lesson students are able to move about the classroom (within bounds) and to practice gross and fine motor movements. The physical aspects of moving and manipulation during an activity fit the physical developmental needs of the early adolescent.

Need for Success

Science also offers a unique possibility for most students to excel at one or more specific tasks. While one student outstrips most in reading and writing activities, others may prove their superiority with certain manipulative or materials centered tasks. Often it is quite possible to achieve one unit objective with different kinds of learning activities, manipulative for some students and semantic for others. Teachers must not forget that science can and should bring success to all students. Planning a variety of learning activities where each child's positive self-concept can be enhanced will lead to future positive feelings about self, science and school in general. Success will breed success.

Grouping

Because of the importance of the peer group, both small group and individual activities must be planned. Within a group individuals must learn how to provide leadership as well as become good followers. The natural give and take inherent in this activity, where success depends upon cooperation, is a secondary goal of science that should not be overlooked. Individual efforts are also important for instilling a sense of responsibility in the early adolescent for his own learning. Cultivating independent work skills can be accomplished with an assortment of techniques including independent projects, science fairs and learning centers. Through repeated exposures to various grouping techniques, it is hoped that a self-identity of a contributing, thinking individual can be developed.

Variation, Growth and Development

Science classes during the middle school years also need to deal with the cluster of concepts involved in individual variation, growth, development and change. The rapid physical changes each student is undergoing need to be put into the context of other students and the whole developmental process. Attention can be focused on these issues via units on the human senses which stress variation as a normal part of every human ability. Various portions of units emphasizing the life cycle of a particular plant or animal could be the stepping stone to a general discussion on the human life cycle and especially the changes important during early adolescence. The general awkwardness, sexual maturity and beginnings of acne difficulties are all part of this set of normal changes. Impromptu discussions of student feelings about these and other transformations can help put the entire process into perspective.

Characteristics Of Middle Grades Students

Just what capabilities make the middle school child unique? Several broad categories are apparent and each will be dealt with in sections that follow.

Cognitive Development

Piagetian Research

Piaget (1963) and his co-workers defined four basic, sequential stages in the development of logical thinking abilities, (sensory-motor, preoperational, concrete operational and formal operational). The concrete and formal operational stages are of greatest concern to the children and teachers of grades four through eight because most children of this age (9-13) can be classified in one of these categories or in a state of transition. Figure 1 outlines some basic descriptive differences between the two stages as well as important age limits for each.

Operationally defined, the formal thinker can use five modes of reasoning: identification and control of variables, proportional reasoning, combinatorial reasoning, probabilistic reasoning and correlational reasoning. The concrete thinker cannot use these thinking patterns. He is more reliant on problem solving strategies involving concrete objects and situations. For more information about this topic the reader should see *Science Teaching and the Development of Reasoning* (Karplus *et al*, 1977).

While an intimate understanding of these modes of thinking is unnecessary for most middle grades science teachers, at least a passing knowledge of each mode is important. Being able to identify formal reasoning patterns in certain science tasks is a requisite skill for the teacher who wishes to gear instruction to the student's level. As we shall see in a later section, this is expecially important for middle grades science.

Brain Growth Research

Recent research into the nature of brain growth and cognitive functioning has tended to substantiate the four general stages outlined by Piaget. After the age of 18 months the number of brain cells in the typical human does not increase. However, the complexity of the neural networks does develop by the addition of thousands of interconnections among neurons. This growing complexity is thought to show itself in terms of additional cognitive abilities.

Most importantly, brain growth also occurs in stages. Considerable increases in brain growth roughly occur between ages 3-10 months, 2-4, 6-8, 10-12 and 14-16 years. The years between these growth spurts tend to show a plateau effect with little increase in neural complexity. Brain growth researchers state that the spurts they've identified roughly correspond to the ages given for transition from one stage to another in the Piagetian framework. Herman Epstein (1979), one of the leading writers in this area, states, "It can be seen that there is a brain growth stage on the onsets of Piaget stages whose ages are as classically given by Piagetians." Later in the same article Epstein states, "The natures of the Piaget stages are such that there is a qualitative change in mental functioning at each of the onset ages, as would be expected if there is a very significant increase in neural complexity."

When Is Formal Operational Reasoning Acquired?

Both Piaget and the brain growth proponents concur that the **onset** of formal operations generally begins around ages 11 or 12 and that this age is highly variable depending on individual development. More importantly, while the onset age of a stage was of minor importance to psychologists like Piaget, it is a major concern in education since educators and especially middle grades educators would like to generalize about appropriate teaching methods and materials for school children.

Commencing with Lovell in 1962, evidence began accumulating that not all children move from concrete to formal operations at age 11 or 12 as Piaget asserted. In fact, a great discrepancy between research findings and theory has become evident. Chiapetta (1976) states that most (over 85 percent) adolescents and young adults have not **fully** developed formal operational abilities. Renner, *et al*, (1978) tested almost 600 students from grades 7-12. Only 17 percent of the seventh graders, 23 percent of the eighth graders and 34 percent of the twelfth graders exhibited formal thought processes. While other writers might disagree with these specific numbers, the overall generalization that can be drawn is that most children in middle and junior high schools do not use abstract reasoning abilities. Considering these results, Piaget (1972), himself, has reassessed his original sample, hypothesizing that they were a privileged group and thus showed accelerated abilities. He further stated that if formal operat ..s do not appear between 11-15 years of age as he originally hypothesized, they should do so by the tin ıost subjects are 20 years old. This last assertion has not yet been substantiated. The effect these findi ɜs may have on middle school science instruction will be discussed in a later portion of this chapter.

Physical Development

Perhaps the most striking aspect of early adolescent development can be seen in the physical changes that occur to children during this period. Students undergo accelerated physical growth, often increasing substantially in height, weight and musculature over a relatively short period of time. Because bone and muscle growth do not proceed at the same rate, awkwardness and temporarily poor coordination often result. Secondary sex characteristics also begin to appear at this age.

In the Boyce Medical Study (Eichhorn, 1979) a thorough documentation of the range of physical development among middle school children was conducted. Ten medical specialists conducted detailed physical examinations of 487 students between the ages of 10 and 14 years. Dr. Allen Drash concluded that while the overall general health of the students was excellent, that physical and sexual maturity at any particular age was extremely variable. Some 14-year-olds were essentially still children while certain 11-year-olds were sexually mature. Thus to describe a child in this age range by age may not be as appropriate as a description of physical and sexual maturity.

The importance of these differences lies in the child's own self-concept. Dr. Ronald Eichhorn (1979) explains.

> "It is particularly crucial that teachers understand the implications of growth and the possible effects on youngsters and the education process.
>
> There is considerable evidence that as physical r. aturation occurs, students' attitudes, interests and value patterns undergo comparable change. It is these changes which provide educators with the need to reassess programs for the transescent learner."

Social and Emotional Development

The social and emotional development of middle school youngsters is also unique. Again signs of the child intermingled with the adult are commonplace. Georgiady and Romano (1977) describe it thus.

> "The transescent is an extremely complex and ambivalent individual, still very much a child in many respects. His interests and behavior are much like those of students in elementary grades. He requires direction and security. Yet he is not always so. His ambivalence is manifested by frequent spells of maturity, though none of these are displayed consistently. The child in him comes through when he expresses exuberance and enthusiasm about something which captures his interest. In this mood, motivation is easily accomplished. However, in his transitional state of development, he often lapses into a passive mood more characteristic of older children."

Of major concern to middle school students are the physical and social changes that are occurring to them and around them. The peer group is now **the** comparison group for the early adolescent preoccupied with his role within that group. Wiles and Bondi (1981) state, "The **self** is an all-important preoccupation of young people and they assume that what is common to everyone is unique to them." Self-conscious behavior or embarrassment is quite prevalent.

The importance of the peer group can also be seen when the early adolescent attempts to be the center of attention. Wiles and Bondi write, "Groups of young adolescents sometimes contrive to create an audience by loud and provocative behavior. What is of immediate interest to them often annoys adults within listening range. The pervasive imaginary audience of young adolescents accounts for both their self-conscious and their boorish public behavior."

Developmental Variability

Perhaps the most important concept to be understood when discussing the general development of middle school children is that no one model of development exactly fits any one child. The broad generalization regarding physical growth is also true for intellectual development as well as social and emotional growth. Variability among individuals is more the rule than the exception. Age grouping in middle schools only emphasizes this variability.

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Curriculum Planning For Middle Grades Science

Planning for science instruction in the middle grades is a continuing process. Major dimensions of the process include (a) needs assessment, (b) unit selection, (c) specification of unit goals and objectives, (d) implementation of student activities and teaching methods designed to help learners attain instructional objectives and (e) evaluation. These dimensions are addressed by all curriculum coordinators as well as middle school science teachers. The degree to which the dimensions are addressed depends on the professional educator's role. For example, a county curriculum coordinator may wish to focus on development of a local guide that addresses each dimension but focuses on essential skills. On the other hand, a seventh grade teacher may wish to focus on alternative activities designed to help students attain a specific behavioral objective. In both instances there is no rejection of any of the major dimensions of the planning process. The difference is seen to arise from the role each person is filling at a given point. Because the planning process is basic to the curriculum coordinator and the middle grades teacher alike, it seems appropriate to discuss the elements of each dimension.

Needs Assessment

Needs assessment is a procedure whereby curriculum coordinators and teachers can determine where students have been, where they are currently, and where they should be in relation to a set of goals. Needs assessment on a large scale involves development of a comprehensive questionnaire, interviews, and much data collecting and processing. The complexity of the needs assessment procedure and suggestions for implementation are described by English (8) in *Needs Assessment: A Focus for Curriculum Development.*

From the science teacher's point of view, the results of a needs assessment should be embodied in the curriculum being taught. That is, the science curriculum being implemented in the middle school should address the needs of learners which previously have been ascertained through some reasonably valid procedure. In addition, the needs assessment procedure should address the unique physical, socio-emotional and intellectual characteristics of the middle school learner. A suggested format for a science curriculum guide including the various components that a locally developed guide needs is included in Appendix II.

Unit Selection

The instructional units selected to meet the needs identified should reflect the diversity of learning styles, teaching (delivery) modes, learner and teacher interests and unique school and community resources. Both long and short term units should be considered ranging from a single week to nine weeks in length. The units which are a part of this document are examples of thematic units based on an acceptance of individual learner and teacher differences. Each can be used as a model for local development.

Goals and Objectives

Goals are broad statements of important ideas and desirable values. Goals for science in the middle grades may originate from within the school or community or they may be adapted from other sources such as the American Association for the Advancement of Science, National Science Teachers Association and its affiliates, and the National Assessment of Educational Progress.

A resource that provides direction in terms of goals and objectives for middle school science in Georgia is *Essential Skills for Georgia Schools* (10). Science curriculum coordinators and teachers can use this valuable document as one aid in formulating goals and objectives regarding middle school science concepts and demonstration of skills. It can also help curriculum coordinators and teachers in a school or community to assess the scope of a current science curriculum. Objectives are more specific than goals because they state what the learner should be able to do as a result of having gone through the educational process. Objectives are usually referenced to learner performance rather than teacher performance and are often referred to as performance objectives.

Performance Objectives. Statements that clearly specify observable learner action are called performance objectives. Performance objectives state a task or activity, the conditions under which the learner will perform, and specify how well the learner must perform. Consider the following example. Given ten leaves which have been labeled with letters beginning with **A**, the student will write, in 60 seconds, the letters for monocots with 80 percent accuracy. Analysis of the objective yields the following components, each of which is common to all performance objectives.

Task—student will **write** the letters

Conditions—given **10 leaves . . . 60 seconds**

Criterion or level of acceptability—with **80** percent accuracy

Conditions of performance may be viewed as the materials needed by the learner to perform the objective. Any other circumstances such as time and place should also be included as part of the conditions for performance.

Criteria are the degrees to which performance must occur before one can say that an objective has been attained at a minimum level. In other words, the level of acceptability. The minimum level may not be the same for every learner; it may be higher for some learners. The point is that there must be an absolute minimum level. If performance falls below the minimum level, performance is judged as inadequate and the objective is not attained.

Observable performance requires that the teacher use terms which imply measurable results. Some common infinitives include **to write, to list, to spell** and **to walk.** Actually, any term may be used if it denotes a clearly observable behavior or can be defined operationally.

Categories of objectives. In addition to the mechanics of formulating goals and writing objectives, science curriculum coordinators and teachers are faced with the task of categorizing objectives. For example, an objective may be classified as (a) cognitive, (b) affective or (c) psychomotor. The objective may be classified further as belonging to one of several levels in a particular domain. Other taxonomies are also available and useful. Major references such as **2, 13, 18** should be consulted with regards to the efficacy and techniques of classifying objectives.

Planning to use goals and objectives. Planning in the middle school involves more than writing objectives, specifying teaching procedures, creating student activities, selecting materials and evaluating learner outcomes. Middle grades science teachers have to plan with other teachers. That is, middle grades science teachers may be members of interdisciplinary teams responsible for the instruction of 60 to 150 or more learners. The team approach to teaching may result in each team member planning lessons that fit a unit theme cooperatively developed by the teaching team. The following questions are offered as important points for consideration in team planning for science teaching in the middle grades.

Does the unit title encompass a broad range of concerns or problems to be solved?

What are the major goals of the unit?

Is there a listing of all appropriate science facts, concepts, process skills, generalizations and values?

Are all objectives clearly stated?

Have inquiry activities been included in the unit?

Are activities appropriate for the developmental levels of learners?

Are science activities included for enrichment and remediation?

Have science learning centers been planned?

How will the team evaluate the success of the unit?

Have community resources (*i.e.*, people, things, and places) been identified?

Are audiovisual and other materials and equipment available and ordered?

Have plans been made flexible for scheduling field trips and other extended activities?

Have students been included in the planning process?

In addition to the challenges of lesson planning from the perspective of an interdisciplinary team approach, generic competencies provide guidelines for effective planning. The *Teacher Performance Assessment Instruments: A Handbook for Interpretation* (5) lists competencies essential to good planning. Middle grades science teachers should become familiar with the following five competencies and their implications for successful planning.

Plans instruction to achieve selected objectives

Organizes instruction to take into account individual differences among learners

Obtains and uses information about the needs and progress of individual learners

Refers learners with special problems to specialists

Obtains and uses information about the effectiveness of instruction to revise it when necessary

Implementation

Implementation is the process of carrying out teaching methods designed to help students attain goals and objectives. Implementation assumes that goals and objectives have been specified and that sufficient materials and appropriate student activities have been selected.

Equipment and materials. The ideal approach to selecting equipment and materials is to develop detailed descriptions of learner activities and teacher demonstrations that are essential to the attainment of goals and objectives of the middle school science program. With these detailed descriptions it is possible to identify and quantify science equipment and materials.

Selection of equipment and materials, in many instances, requires teachers to exhibit an admirable degree of resourcefulness in the absence of readily available supplies. Curriculum coordinators, middle school science teachers, and principals may wish to work cooperatively to access minimal equipment and materials necessary for student activities and teacher demonstrations.

Teacher editions of text series and validated science programs can aid in the development of an inventory of essential supplies. Most textbook publishers include listings of essential or suggested supplies needed by teachers and students who use their books. A comprehensive list of companies that sell supplies may be found in the *Guide to Scientific Instruments* published by the American Association for the Advancement of Science.

Activities. As in the case of selecting science equipment and materials, the middle school science teacher should use all available sources. Suggestions most helpful are teachers editions of text series and the options found in validated science programs such as SAPA-II, SCIS, and ESS, USMES. Many different activities appropriate for a given objective can be found in science methods books, *Science and Children*, other National Science Teacher Education publications and in trade books.

Essential criteria for selecting learner activities are identified by McNeil (21). Some of the criteria include providing appropriate practice, allowing for learner's experimental background, providing opportunities for manipulating, simplifying the learning task and providing for feedback. These and other criteria derived from purposeful discussion among middle school science educators can be invaluable in screening and selecting learner activities.

Teaching methods. Materials and activities are not selected without some attention to options among teaching methods. The way a teacher plans to teach a unit on electricity, for example, has a direct influence on the selection of materials and activities. This relationship is clarified in the section of this guide dealing with instructional methodology.

Much useful information regarding teaching methods and performances in the classroom is found in the *Teacher Performance Assessment Instruments: A Handbook for Interpretation* (5). Two sections of the book address implementation in terms of classroom procedures and interpersonal skills. The competencies and indicators in the sections dealing with implementation are appropriate for all middle school teaching personnel. The six generic competencies for classroom procedures are these.

Uses instructional techniques, methods, and media related to the objectives

Communicates with learners

Demonstrates a repertoire of teaching methods

Reinforces and encourages learner involvement in instruction

Demonstrates an understanding of the school subject being taught and demonstrates its relevance

Organizes time, space, materials and equipment for instruction

In addition to the competencies for classroom procedures, there are three competencies related to interpersonal skills. The following competencies focus on teacher enthusiasm, warmth and ability to manage the classroom environment.

Demonstrates enthusiasm for teaching and learning and the subject being taught

Helps learners develop positive self-concepts

Manages classroom interactions

Any given teaching method should provide evidence that the generic competencies have not been overlooked. Indeed, teachers should find the competencies useful in developing the best possible mix of materials and activities for effective and efficient implementation of the middle school science curriculum.

Evaluation

Evaluation is an integral dimension of the middle school science curriculum planning process. It requires that some value be placed on information collected in attainment of science program goals and objectives. For example, evaluation of a middle school science program may identify goals which were not attained at an 80 percent level by a majority of learners. This example indicates that the criterion is 80 percent correct responses by a majority of learners. It is obvious that a value judgment was made when the criterion was set at 80 percent. It is also obvious that a value judgment was made with reference to how many learners should be able to attain the cutoff score. Curriculum coordinators and middle school science teachers can expect to make many similar value judgments in addition to deciding upon the kind of instruments, and how the data are to be used.

Norm-referenced judgments. A traditional approach to making judgments about achievement involves comparing a learner's score to a peer group's mean score. Norm-referenced judgments are appropriate when the teacher wishes to group learners based on achievement scores. They are also appropriate when reporting procedures require teachers to report an individual learner's progress relative to the average class performance. In any event, norm-referenced judgments imply that the outcomes of individual-to-the-group comparisons have much value and, therefore, justify the procedures used.

Criterion-referenced judgments. Judgments based on the comparison of a learner's performance with some specified performance criteria are referred to as criterion-referenced judgments. Teachers who make criterion-referenced judgments are **not** comparing an individual's performance to the class "average." However, the teacher is assessing what has been learned with reference to some previously stated performance level. For example, the learner may attain an objective by naming six of ten chemical elements when given symbols for the elements. In this example, the criterion is six correct names and is not relevant to what the learner's peers may have done in terms of a class mean for the same test. In the case of criterion-referenced judgments, the value placed on comparing a learner's performance to a clearly stated performance standard is great enough to justify the procedures used.

Self-referenced judgments. Judgments concerning achievement can be made by comparing a learner's performance to the same learner's previous performance. Such comparisons are useful when making judgments about learner attitude change or knowledge growth over a period of time. Data from comparisons are useful in helping middle school learners understand the degree to which they are making progress in science.

Cognitive and affective outcomes. Cognitive outcomes are the knowledge, comprehension and problem-solving skills acquired by learners. The cognitive domain of intellectual operations is, by far, the most frequently and rigorously evaluated. An excellent document that provides much information and an excellent bibliography on measuring cognitive outcomes is *Basic Measurement and Evaluation of Science Instruction* by Doran (7).

The domain of intellectual operations dealing with attitudes has not been extensively evaluated. However, there are many options available to coordinators and teachers alike, including forced choice items, interviews, checklists, informal discussion, value clarification, the semantic differential, reports and term papers. Most of these options for evaluating affective outcomes in middle school science are described by Doran (7). In addition, the following points (p. 72) are offered as items to be kept in mind when developing means of assessing affective outcomes.

- The kinds of questions asked are as significant as the method of questioning used.
- Feedback during program development and during actual collection of data is essential.
- Data collected do not always have to be in the form of a grade such as **A** or **B.**
- The purpose of the evaluation should be accurately and honestly communicated.
- Data should be used for the stated purpose only.

Instructional Methodology For Middle Grades Science

The middle school science teacher is faced with the problem of selecting rather than developing effective instructional methodologies. This is due to the fact that many methods are clearly described in the literature dealing with pedagogy. For example, Joyce and Weil (16) list 16 models of teaching which can be used to modify an entire curriculum or course, select appropriate instructional materials, and to guide teacher performance. The inductive model developed by Suchman (27) provide the middle school science teacher with guidelines for implementing methodologies especially useful in problem solving. Indeed, the inductive approach to problem solving is emphasized in most college science methods courses, teacher editions of text series, and validated science programs.

Problem Solving Through Inquiry

There are two major reasons why methodologies based on inquiry are essential in the middle school.

1. Process Skills - There are basic process skills common to all fields of learning. The process skills comprise the language of inquiry and are essential for problem solving.
2. Cognitive Development - The transescent student is moving from the concrete to formal operations stage of development. Developmentally, the student is ready or approaching a readiness for working with the integrated process skills.

Since methodologies based on inquiry are essential for teaching in the middle grades, the teacher should have a knowledge of the following inquiry skills.

Observing
Classifying
Using numbers
Using space-time relationships
Measuring
Communicating
Inferring

Controlling variables
Defining operationally
Predicting
Interpreting data
Formulating hypotheses
Experimenting

Inquiry skills are fully elaborated upon in *Science - A Process Approach II* (24). Similarities between the preceding listing of the "language of inquiry" and the following items taken from a social studies methods textbook should be sufficient to convince the middle school science teacher that the language of inquiry is not confined to life, physical and earth sciences but to the work of the historian, the anthropologist, the sociologist and the psychologist, to mention a few.

Identifying problems and questions for study

Making inferences and drawing conclusions from data

Using evidence to test hypotheses

Predicting possible outcomes

Getting data from a variety of sources (Jarolimek 14, p. 72).

Three practical approaches to problem solving, rational, discovery and experimental, are described by Esler (9, p. 35-53). The approaches contain elements of Taba's (28) inductive model and Suchman's (27) inquiry training model and, therefore, present the teacher with options rather than a single approach for teaching science in the middle school. Each approach is described in this section of the guide.

Rational Approach

Inquiry through a rational approach. The rational approach is basically a teacher-student discussion interaction. Questions are asked that lead students to recognize and clearly state one or more problems, make inferences, state hypotheses and suggest possible ways to test hypotheses. The approach requires that appropriate responses of students be positively reinforced and phrased to encourage student on-task behavior. Consider the following scenario.

SETTING

Large group

OBJECTIVE

Learners will identify variables that affect frequency of pendulum.

PREREQUISITES

Knowledge of the terms (a) cycle—a single back and forth movement of pendulum; (b) amplitude—distance in degrees from vertical and (c) bob—weight.

MATERIALS

String (attached to meter stick on top of a cabinet in the classroom), Large metal bolt (attached to other end of string)

Teacher (Putting the pendulum into motion without making any comments for 10 to 15 seconds) *What have you observed during the past 10 to 15 seconds?*

Student(s) *The pendulum is moving back and forth.*

Teacher *Yes. What else can you observe about the movement?*

Student(s) *It seems to be coming to a stop.*

Teacher *Well, it does seem that the amplitude is not as great. I wonder if there is some way we can measure how often the pendulum moves back and forth?*

Student(s) *We can time it! We can pull back the bob and count the cycles during one minute.*

Teacher *Excellent suggestion! We will call the number of cycles per second the* **frequency** *of the pendulum.* (Writes the word and definition on the board.)

Teacher *Are there any other suggestions as to how we can determine the frequency?*

Student(s) *Yes! We can count the cycles for fifteen seconds.*

Teacher *Very good suggestion! How could we then find the frequency for one minute knowing only the frequency for fifteen seconds?*

Student(s) (silence)

Teacher *How many 15-second periods of time are there in one minute?*

Student *Four. There are four! We can multiply the cycles by four to get the frequency for one minute.*

Teacher *Good thinking, Mary! Let's try your idea with our pendulum. Mary, you count the cycles when I say go. Go!* (15 seconds pass as the pendulum swings)

Teacher *Stop! How many cycles, Mary?*

Student *Fifteen cycles. Fifteen cycles in 15 seconds. Fifteen times four is the frequency. The frequency is 60! Sixty cycles per second.*

Teacher	*Goodness, Mary! You must have a computer in your head. Does everyone agree with the frequency? . . . Leslie, you seem puzzled.*
Student	*I know how to compute the frequency, but I didn't count 15 cycles. I counted only 13 cycles.*
Student	*I don't agree with Leslie. I counted 16 and one half cycles.*
Teacher	(Explains error of measurement—accepts student suggestions that several people should count and take an average of the counts—accepts suggestion that a stop watch might be more accurate than clock in room.) *We can now compute frequency and we agree that just because we don't make the same measurements we are not careless. Now, does anyone want to try to identify a problem regarding pendulums?*
Student	*Yes! I want to know if the frequency becomes greater when the bob is pulled further back.*
Teacher	*You want to find out if frequency is affected by amplitude?*
Student	*Yes. We can do it by pulling the bob back farther and farther each time.*
Teacher	*That is a possibility.* (Pointing to the term **amplitude** on the board) *We can increase the amplitude of the pendulum. What can we hypothesize regarding the frequency of the pendulum?*
Student(s)	*The frequency will increase. I hypothesize that the frequency of the pendulum will increase when the amplitude is increased.*
Teacher	*Very well, Tim. How can we test your hypothesis?*
Student	*Pull the knob back 10 degrees and then 20 degrees and compute the frequency.*
Teacher	*Tim, here is a protractor. Why don't you get Martha to help you with the experiment to test your hypothesis?* (students complete three observations at 10 degrees and three observations at 20 degrees and compute the frequency)
Student(s)	*It doesn't seem to make a big difference. The frequencies were just about the same.*
Teacher	*Thank you, Tim and Martha, for doing the experiment. Now, Rita, do you think it would make a difference if we increased the amplitude to thirty and then forty degrees?*
Student	*I don't know. It might make a difference since the angle will be greater.*
Teacher	*What do you hypothesize?*
Student	*I hypothesize that the frequency will increase as the amplitude increases.*
Teacher	*You have a well-stated hypothesis, Rita. Why don't you and Wanda test the hypothesis?* Students make three observations at 30 degrees and three observations at 40 degrees and compute the frequency.
Teacher	*What do your data mean to you, Rita and Wanda?*
Student(s)	*Our data show that frequency is not affected by amplitude. We have to reject our hypothesis.*
Teacher	*You seem to have collected your data carefully. You are really beginning to think and work like scientists.*
Teacher	*What can we conclude from our experiments and data collected today?*
Student	*We can conclude that amplitude does not affect the frequency of a pendulum.*
Teacher	*Yes, Fred, that is a reasonable conclusion. Now, what must we do before we can make a generalization about the relationship between the amplitude and frequency of pendulums?*
Student	*We will have to do many more experiments.*
Student	*We might do some experiments using different weights.*
Student	*We could all do experiments using different lengths of string.*
Teacher	*Each suggestion is excellent and should be developed. First, let's review the steps that led us to where we are at this moment.*

It is obvious from the preceding scenario that the teacher acted as a provocateur by asking questions that led students to make inferences, state hypotheses, collect data and draw conclusions. The teacher **did not tell** the students what the problem was or how to set up an experiment to test student generated hypotheses. The students were encouraged by teacher questions and comments to generate the problem, state and test hypotheses, record data, draw conclusions and make appriopriate comments generalizing their conclusions about other pendulums. The teacher was careful to not neglect the wisdom of having students review the steps they had gone through.

Many variations on the rational approach are possible and no teacher should feel that the questions in the example scenario are exhaustive. What should be kept clearly in mind, regarding recall-type questions, is that only the most essential questions were asked. It should also be noted that the teacher told or gave very little information. (NOTE: An excellent guide to question asking is Sanders (23) *Classroom Questions*.)

The following series of steps should be useful in planning to conduct inquiry through a rational approach.

Syntax of Inquiry
Rational Approach to Problem Solving

Present students with a problem stimulus—something that sparks their interest.

Ask questions that require students to

make accurate observations.

identify problem(s) and variables.

state one or more hypotheses.

design an experiment to test hypotheses.

collect data and use to reject or support hypotheses.

make conclusions and appropriate generalizations.

Review the steps of the rational approach.

(NOTE: Relevant contributions and essential information should be written on the board or chart paper during the course of the lesson.)

Pure Discovery

Inquiry through pure discovery. The pure discovery approach can be starkly contrasted to the rational approach as well as to other approaches of inquiry. Pure discovery requires that students manipulate materials. The teacher reviews rules for working in small groups and discusses safety rules. Students are told to find out what they can about the materials which they will be manipulating. The class is then broken into small groups with each group having one person responsible for collecting materials supplied by the teacher. Once students start manipulating the materials, the teacher moves from group to group asking questions that require students to make careful observations, identify variables, formulate problem statements and use the other skills and language of inquiry. Since the pure discovery approach does not lend itself to as much teacher domination as the rational approach, it is likely that not one but many problem statements will be forthcoming. It is also possible that the teacher will find that the amount of time spent in pure discovery is less than that spent in other approaches to inquiry. However, the pure discovery approach is not to be overlooked as an option, especially when students have not had opportunity to manipulate particular materials. Consider the following scenario.

SETTING

Large group, small groups.

OBJECTIVES

Learners will state one or more problems, make appropriate observations, construct circuits and explain how they work.

PREREQUISITES

Knowledge of the terms circuit, power source, load, conductor. Prior experience constructing a series circuit using one bulb, one battery, and knife switch.

MATERIALS

Two bulbs and holders, two batteries, one knife switch, wire and wire stripper.

Teacher (Holding-up-and-naming each material) *Now that we have reviewed our materials and rules for small group work, you will have 15 minutes to find out all you can about the materials and what you can do with them. You have already worked with a simple circuit containing a single bulb as the load. You will note that you now have two bulbs and, in addition, two batteries.*

Teacher *Now, let's break into our groups.*

Group 1 *What do you want us to do? I don't understand what we are to do.*

Teacher *Can you make the bulb light in ways different from the way you did the last time we worked with circuits? Try to find out everything you can about the materials in the remaining time.*

Group 2 *We can make the bulb light with one battery. See!*

Teacher *Very good. You remember our work with a simple circuit from the last time we worked with circuits. What else can you do?*

Student(s) *We can try to make both bulbs light up.*

Teacher *That's a challenging problem!*

Group 3 *Why don't both bulbs light up?*

Teacher *What do you know about a complete circuit?*

Student(s) *Electrons can flow through a complete circuit.*

Teacher *That's absolutely correct. But can electrons flow through your circuit? How can you know if electrons will flow through your circuit?*

Student(s) *We can trace the circuit to make sure it is complete.*

Teacher *That's a good idea. Why don't you trace your circuit and see if there is a problem.*

Group 4 *We can make two bulbs light up, but when one is taken out of the socket the other one goes out. Why?*

Teacher *Is your circuit complete when both bulbs are lighted?*

Student(s) *Of course. But why does one bulb go out when we unplug the other bulb?*

Teacher *What must happen when you unplug one of the bulbs?*
(teacher continues to move around the classroom asking questions in order to help students recognize problems and state hypotheses.)

An appropriate closure for pure discovery could be a class discussion of observations, noting similarities and differences among observations, hypotheses and conclusions by various groups. Discussion lends itself to development of subsequent lesson plans using a rational approach to a number of problems identified by the students. The teacher may also capitalize on the hypotheses and problems raised by preparing one or more lessons using guided discovery or an experimental approach to inquiry. These approaches are discussed in the following pages.

The role of the teacher using the pure discovery approach is summarized in the following.

Syntax of Inquiry
Pure Discovery Approach to Problem Solving

Establish or review class rules for group work.

Show materials to students and name each item. Point out any precautions regarding safety and proper handling of materials.

Instruct learners to manipulate materials and to record their observations within a given period of time.

Break into predetermined groups and provide access to materials.

After the time has elapsed, supervise the return of all materials and assemble students into large group.

Discuss discoveries and ask questions that require learners to evaluate their work in terms of possible problem statements, hypotheses, identification of variables, tests of hypotheses and possible conclusions.

Prepare lesson plans which include follow-up of discussion. The follow-up could include independent small group work or individual work using inquiry through guided discovery or the experimental approach.

Guided Discovery

Inquiry through guided discovery. Guided discovery provides opportunities for students to solve a common problem. A major difference between guided discovery and pure discovery is that teacher questions focus student attention on a specific problem identified by the teacher or the students. Also, students have access to appropriate materials only after the problem has been clearly expressed. For example, the teacher may ask, "What affects the frequency of a pendulum?" After the question is clarified, students may break into small groups as in the pure discovery approach to work with appropriate materials in seeking solutions to the problem.

Elements of the guided discovery approach are outlined in the following.

Syntax of Inquiry
Guided Discovery Approach to Problem Solving

Establish or review class rules for group work.

Show materials to students and name each item. Point out any precautions regarding safety and proper handling of materials.

Present problem and clarify any terms not understood by learner.

Break into predetermined groups and provide access to materials.

Supervise learner's work while asking questions that keeps learner on task.

After time has elapsed, supervise the return of all materials and assemble learners into large group.

Discuss discoveries, hypotheses, variables, tests of hypotheses and conclusions.

Prepare lesson plans which include follow-up of discussion. The follow-up could include independent small group work or individual work using additional inquiry through guided discovery activities or the experimental approach.

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Both pure and guided discovery approaches can be used in conjunction with the rational approach. It should be quite obvious that any one of these approaches requires learners to do far more problem solving than simply reading and answering questions in a text book.

Experimental Approach

Inquiry through an experimental approach. Inquiry through an experimental approach is a third problem-solving approach. The experimental approach represents the summit of problem solving appropriate for middle school learners who are developmentally ready or approaching readiness to deal with the language and syntax of experimentation.

The experimental approach differs from the rational and discovery approaches previously discussed. The major difference is that the experimental approach emphasizes the necessity for learners to follow specific steps. Although the teacher will continue to ask types of questions common to the rational and discovery approaches, the questions appropriate to the experimental approach are clearly keyed to well-defined procedure which learners must follow. In addition, the inquiry or process skills are more complex than those which students may or may not have been exposed to in rational and discovery approaches. For example, students may not have been required to define variables operationally. Students may not have been instructed as to how variables could be controlled, or for that matter, that there are different types of variables. Indeed, the rational and discovery approaches may not have provided students with sufficient practice and reinforcement for developing a clear plan or approach for problem solving. The experimental approach attempts to combine the essential elements of the rational and discovery approaches to produce a structured but efficient syntax for problem solving.

The experimental approach lends itself to individual and small group settings. Independently developed projects using the experimental approach can fit within a learner's schedule if a given middle school endorses the concept of independent study by providing a block of time for that purpose. The same block of time can also be used for small groups using the experimental approach. Consider the following scenario in which the experimental approach is implemented.

SETTING

Large group

OBJECTIVE

Learners will construct an electromagnet and determine the effects of the number of turns of wire on the strength of the magnet.

PREREQUISITES

Prior knowledge of definition of electromagnetic; knowledge of series circuit containing knife switch, one or two bulbs, one or two batteries; knowledge of graphing skills.

MATERIALS

Insulated wire, knife switches, batteries, iron bolts or rivets, paper clips and graph paper

Teacher *Yesterday we discussed Oersted's discovery which indicated that a magnetic field surrounds a wire carrying electric current. We also discussed the possibility of using that idea to construct an electromagnet. Today, we want to design and carry out an experiment to solve a problem related to what we have already discussed. The problem is, what are the effects of increasing the number of turns of wire on the strength of an electromagnet?* (Teacher writes problem on board.)

Student *The magnet will be stronger!*

Student *The more wire you wrap around a nail, the stronger the magnet!*

Teacher *Can someone raise a hand and state an hypothesis?*

Teacher *Thank you for raising your hand, Jim. Can you state an hypothesis?*

Jim *Yes. The more wire you wrap around a nail, the stronger the magnet.*

Teacher *Fine, Jim. You hypothesize that the amount of wire makes an electromagnet stronger. I wonder if anyone else can state the same hypothesis in different words?*

Student *The strength of an electromagnet depends on the number of turns of wire.*

Teacher *Very fine, Susan.* (Teacher writes hypothesis on board.) *You and Jim are thinking along the same line. Are there any other hypotheses related to our problem?* (Teacher points to problem written on board.)

Student *I think the electromagnet will be twice as strong if twice the turns are added.*

Teacher *What do you mean by that, Mary?*

Mary *I think an electromagnet will pick up twice as much weight if the turns are doubled.*

Teacher *Can anyone state Mary's idea as an hypothesis?*

Student *I think an hypothesis would be that the strength of an electromagnet doubles when the turns are doubled.*

Teacher *Yes, Martha. I think you and Mary are on the same track. Humm . . . What if we say the strength of an electromagnet is doubled when the turns are doubled?* (Teacher writes on board.) *Is that O.K. with you, Mary and Martha? Does that say the same thing you were saying?*

Students *Yes. It means the same thing.*

Teacher *Very well, we now have two hypotheses. What are the variables involved in this problem?*

Student *The manipulated variable will be the number of turns.*

Teacher *Ted, you have certainly identified a manipulated variable. Good thinking! Are there other variables that will be manipulated?*

Student *I'm not sure it's a manipulated variable, but we ought to make sure that we all use the same kind of wire.*

Teacher *You are absolutely right, Ted. We need to control certain variables and one of the variables that should be controlled is the kind of wire.*

Student *We better make sure the turns of wire are the same distance apart.*

Teacher *Thanks, John. You have identified another variable that should be controlled. So far we have identified one manipulated variable and two variables we should control by keeping each one of them the same during the experiment.*

Student *What about the responding variable? What is the responding variable?*

Teacher *That's a good question! What variable do we expect to be affected by the manipulated variable?*

Student *The strength of the magnet is the responding variable. It will be affected by the manipulated variable.*

Teacher *Mark is right. How can we define the responding variable? How can we define strength?*

Student *We can define the responding variable by how many things the magnet will pick up. We could use pieces of iron.*

Teacher (Holding up several boxes of paper clips.) *Since we already have some paper clips and since they are magnetic* (teacher attracts several with permanent magnet) *and are all about the same size and weight, let's use paper clips. What shall we call our responding variable?*

Student *Let's call the responding variable* **paper clip power.**

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Teacher *Very well, Mary. Paper clip power it is!* (Teacher writes on board) *We have stated two hypotheses and identified our variables. Now how shall we test the hypotheses in our small lab groups?* (Students and teacher discuss possible procedures using materials available)

Teacher *O.K. We are agreed on the procedure to be used to test both hypotheses. Let's correctly construct and label the axes of our graph paper so that the manipulated variable is on the vertical axis and the responding is on the horizontal axis.* (teacher uses overlay on overhead projector to demonstrate)

Teacher *We are now ready to conduct the experiment. Those persons responsible for lab materials may come forward. Everyone else should form lab stations with your desks.*

After a reasonable period of time the teacher calls for all materials to be returned and for desks to be returned to their former positions. Graphs are displayed and discussed by several groups and the teacher asks questions to determine whether or not the hypotheses should be rejected based on data collected. Questions requiring interpolation and extrapolation may be asked with reference to graphs. It is appropriate for the teacher to tell the students that their results may not "hold up" when conducted under similar conditions. Only until the same results are obtained many times can one make a generalization.

The preceding scenario should be sufficient for exemplifying the syntax of the experimental approach. There may be many variations on the approach. However, the basic elements should be present. The following steps serve as a guide for implementing inquiry through an experimental approach.

Syntax of Inquiry
Experimental Approach to Problem Solving

Select and clearly state problem for experimentation.

Formulate one or more hypotheses.

Identify variables and define operationally.

Develop plan for testing hypotheses.

Acquire and make available all necessary materials to test hypotheses.

Carry out experiment(s) using materials according to previously estalished plans to test hypotheses.

Record data and use appropriate graphs.

Determine whether data support hypotheses.

State conclusions and need for further experimentation while considering possible generalizations.

Classroom Organization

The degree to which middle school students are up and about in the classroom is related to the behavioral objectives formulated by the science teacher. For example, the attainment of an objective through a rational approach would result in little if any student movement about the classroom. On the other hand, if the objective is to be attained through a guided discovery approach, a relatively large amount of student movement may be expected. The lab station concept is one approach to small group work and classroom management. The learning center is another approach to the same problem.

Lab stations in the classroom. One strategy for work in small groups calls for the development of logistical units referred to as lab stations. A lab station consists of two or more students with assigned responsibilities working together in a given space in the classroom. Purposes of lab stations are to

provide opportunities for students to solve problems in an atmosphere of cooperation and sharing;

enhance on-task behavior;

promote question asking through peer interaction;

provide opportunities for students to share materials and relevant ideas in a problem-solving context;

facilitate distribution of materials;

maintain an inventory of materials;

expedite clean-up;

free teacher to supervise and guide students.

The lab station concept emphasizes the necessity for individuals to carry out assigned responsibilities in order for the group to be successful in its efforts to achieve a given objective. Consider the following objective and use of the lab station concept with 30 students.

OBJECTIVE Each lab station will construct at least two different diagrams of complete electrical circuits containing two bulbs in parallel using one and two batteries. Circuits must be constructed to test each diagram. (NOTE: The teacher wants students to apply their knowledge of parallel circuits. Also, the teacher wants students to discover the configurations of batteries in series and parallel.)

MATERIALS Ten large envelopes containing two bulbs and bulb holders, two D-cell batteries, one knife switch, four or five assorted lengths of wire with ends stripped

EVENTS

1. Teacher reviews location of 10 lab station areas (three students per station) to which desks are to be moved.
2. Chart containing responsibilities is posted and reviewed.

   One student in each group is to take envelopes to lab stations and return materials to central location; be responsible for taking inventory of materials prior to using and after using; be responsible for reporting any missing or damaged materials to teacher.

   One student in each group is to record procedures and results of experiments; be responsible for reporting results to class at appropriate time.

   One student in each group manipulates materials after inventory has been taken; is responsible for seeing that other members of the lab station have an opportunity to manipulate materials; is responsible for carefully and slowly describing observations and manipulations to aid recorder in taking notes.
3. Walking and talking rules are reviewed. Only one person from any lab station has permission to be out of desk. (See A above.) Conversation should not be distracting to teacher or another lab station. (Both rules are relatively easily enforced by the teacher who is moving among the lab stations during the time work is taking place.)
4. Amount of time for activities is specified and written on board.
5. Teacher tells students to "Form your lab stations."
6. After stations are formed the appropriate students pick up material packets and return to lab stations and begin carrying out responsibilities.
7. After time expires the teacher blinks the room lights to signal the appropriate students to collect inventory and return materials to a central location. Students begin returning desks to former locations.
8. Teacher conducts discussion of work based on group reports presented by appropriate students from each lab station.

Teachers may modify the sequence of events to conform to their own expectations for small group work. The lab station concept should not increase discipline problems to a level beyond that already present in the classroom when small group work occurs. Indeed, the procedure could serve to reduce discipline problems by making students more mindful of their responsibilities to the group. Furthermore, the teacher's random visits to the various lab stations and the teacher's questions and praise should serve to reinforce appropriate behavior.

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Learning centers in the classroom. The concept of learning centers is another option for individualizing instruction in the middle school. Learning centers can be used by students who finish class assignments or group work early and can profit from self-instructional learning materials. Centers can also be developed to aid students who need additional remedial activities to achieve a given objective.

Learning centers are defined by Klingele (17, p. 102) as "... concentrations of student activities focused in a particular area of a classroom or school." Many learning centers made by classroom teachers are self-contained, portable, and displayed on cardboard panels. The following components should be considered when planning to construct such centers.

Title—comprehensive and catchy, such as "Bug Off" for a center that helps learners differentiate between bugs and other orders of insects.

Objective(s)—statement that tells the learner what he or she is to be able to do.

Procedure—step-by-step instructions on what the learner is to do.

Activities—at least three activities for a single objective should be included in the center.

Materials—everything necessary to complete all activities should be available.

Evaluation—pre- and posttests of concept(s) or skills should be considered as part of the center. An answer key may be provided by the teacher. Also, a place should be provided to collect any materials students complete that need to be checked by the teacher.

Check-in-out—a checksheet of activities should be provided. Learners should check the activities completed by writing in the dates of completion beside their names.

Examples of activities in a center include puzzles, matching games and flashcards, to mention a few. More than 100 activities that can be adapted to learning centers are found in *Creative Sciencing* by De Vito and Krockover (6). Another source of a wealth of ideas is *The Everyday Science Sourcebook* by Lowery (19). Additional resources for the middle school science teacher include *Invitation to Learning: The Learning Center Handbook* (31), "Designing the Learning Center" (25) and "Learning Stations and Science Teaching" (30). *Science and Children, Teacher* and *Instructor* often contain learning center ideas for the middle school.

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Exemplary Units

The following three units are different in style and format. Each of them uses all three elements of inquiry mentioned in the previous section, *i.e.*, rational, discovery and experimental. The units themselves are useful if a teacher is inclined to adopt one intact. However, their primary function is to provide models upon which middle grades teachers may structure units of their own design.

Rational Inquiry

The activities in the detailed plans for large group instruction are well suited for small group investigation. The focus in the large group plan is on oral questioning techniques. The activities should not be omitted. They are central to the large group's arrival at proper conclusions. If it is impossible to provide space and materials for students to do the activities, a teacher-facilitated demonstration becomes imperative.

Esler and Esler (1981) describes three major classes of questions for directing verbal interaction outside the context of a formal inquiry session. The reader is strongly urged to study the reference cited for a more detailed presentation in developing oral questioning skills.

Energy – Plan 1

Topic - Chemical energy

Detailed plan

Grade level - 7

Group category - large group

Content objectives

The children will

name three living classes of biochemical compounds and relate their importance to living things;

describe one way biochemical energy is stored in an organic compound;

apply chemical tests to detect the presence of sugar, starch, protein and fat.

Skill objectives

The children will

conduct experimental chemical tests on biochemical compounds;

observe and interpret the effects of chemical tests on biochemical compounds;

categorize food samples according to their biochemical classification;

communicate by maintaining written records of their experimentation.

Materials

Samples of sugar solution, starch solution, gelatin solution and vegetable oil

Water

Three clear test tubes

Test tube rack

Bunsen burner

Beaker (500 ml.)

Ring stand set-up

Benedict's solution

Iodine solution

Several squares of brown paper bag (5 cms. x 5 cms.)

Biuret reagent

Procedure

1. You may begin this unit with a general discussion proposing the concept that all living systems require a constant supply of biochemical compounds. This concept is generally introduced in the third and fourth grades and your students may recall that most higher life forms require carbohydrates, fats and proteins. If not, develop this scheme for biochemical classification in your initial discourse.
2. Small group experimentation would be the preferred mode of investigation. If conditions do not permit small group application, a student-led demonstration with the teacher as a facilitator will suffice.
3. The laboratory (or demonstration) activity is as follows.
   a. Label three clear test tubes A, B and C, and place them in order in a test tube rack.
   b. Add approximately three mls. of each biochemical compound as follows.

      Tube A - sugar solution

      Tube B - starch solution

      Tube C - gelatin solution
   c. Fill a beaker 1/2 full of water and place the beaker on a ring stand over a Bunsen burner. Bring the water to a slow boil.
   d. Add three mls. of Benedict's solution to Tube A. Heat the test tube in the beaker of boiling water for five minutes. Record all observations.
   e. Add three to five drops of iodine solution to Tube B. Shake well and record all observations.
   f. Add three mls. of biuret reagent to Tube C. Shake well and record all observations.
   g. Take four squares of brown paper and label them sugar, starch, gelatin (protein), vegetable oil (fat). Place one drop of each solution on the appropriately labelled paper. Let stand for five minutes.
   h. Hold each square of paper up to light and observe any changes in the appearance of the paper. Record your observations.
4. When all children have individually recorded their findings for the chemical tests on each biochemical compound, move to verbal interaction with oral questioning techniques.

Eliciting

a. What is the test for starch (sugar, fat, etc.)?
b. How might a food technician take the results of your experiment and use them?
c. If I told you starch and sugar were both carbohydrates, do you think they would respond to the same chemical tests?

Probing

a. Both sugar and starch are carbohydrates. Can you guess why they require different chemical tests for their identification?
b. What biochemical compounds would you expect to find in the following food groups?
c. Can a food, steak for example, contain more than one type of biochemical compound?
d. In what form does the body store simple sugars?

Closing

a. What major classes of compounds have we identified chemical tests for?
b. How might we put these tests to use?
c. What would be a good way to compile and present our findings?

Skeletal plan - This introduction to chemical tests for the presence of biochemical compounds can be further developed in two related problem solving areas.

1. Three questions were presented in the detailed plan that can serve as the focus for further investigation.
   a. If I told you starch **and** sugar were both carbohydrates, do you think they would respond to the same chemical tests?
   b. Both sugar and starch are carbohydrates, can you guess why they require different chemical tests for their identification?
   c. In what form does the body store simple sugars?
2. Now that tests have been established for standard known solutions, unknown substances can be prepared and tested for the presence of biochemical compounds.

Energy

Topic - Work

Detailed plan

Grade level - 5,6

Group category - large group

Content objectives

The children will

state that when a force causes an object to move, work is done;

state that the amount of work done is equal to the size of the force multiplied by the distance an object is moved;

name the metric units (SI) required for the measurement of distance, force and work;

calculate the amount of work done using the formula $W = f \times d$.

Skill objectives

The children will

measure the distance an object is moved;

measure the force exerted on an object;

operationally define work.

Materials - for each lab group

Spring scale (force gauge)

Metric ruler

Rubber bands or string

Paper clips

Three sets of objects (e.g., books, standard weights, small bricks or wooden blocks)

Procedure

1. You may begin this unit with a general discussion that established a formula (work = force x distance) for measuring the amount of work done.
2. a. Without further discourse, move to an application of the formula, W = fxd. Small group experimentation would be the preferred mode of investigation. If conditions do not permit small group application, a student-led demonstration with the teacher as a facilitator will suffice.
   b. Hook the spring scale onto an object from the first set. A rubber band or piece of string can be used to provide linkage with the scale. With a pencil, mark the reference position of the object. Now mark a position 20 cms. from the reference point and move the object to that point by applying the necessary

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pull (force). Record the reading on the scale as the object is being moved. Record all data. Repeat this procedure for all sets of objects and, time permitting, conduct two trials for each object. Record and average the data. Apply data sets for each object to formula, W = fxd. For example

object 1 - science book

force = 1.5 kg or (1.5) (9.8) = 14.7 newtons

distance = 20 cms. or 0.2 meters

work = 14.7 newtons x 0.2 meters = 2.94 newton – meters or 2.94 joules

3. When all children have individually completed the calculations required for their data analyses, have one member from each group present the group's findings.
4. Direct verbal interaction at this point with oral questioning techniques.

Eliciting

a. Can we list the variables we measured?

b. What variable did we measure with the spring scale?

c. What variable did we measure with the meter stick?

Probing

a. What is the unit of measurement for force (distance, work)?

b. Can you predict how much work would have been done if we were unable to move one of the objects?

c. Are there any other ideas?

Closure-seeking

a. Can we draw any conclusions about the differences in the amount of work required to move each object?

b. Why did we measure force at least two times for each object and then take an average?

c. Can you predict how much work would be required to move a 40 kgm object 20 cms.?

Skeletal plan - This instruction on the concept of work can be preceded by mastery of the following content and skill objectives.

1. Given a series of everyday activities, recognize those that are dependent upon gravitational force.
2. Predict how the following factors affect the movement of objects. Forces, friction, unbalanced forces.
3. Design a simple experiment that demonstrates the application of Newton's First Law of Motion (Law of Inertia).
4. Predict what will happen to objects in motion or at rest when some force is applied to the objects.

These objectives can serve as the focus of problem-solving activities leading to the development of the prerequisite skills related to the concept of work.

Energy

Topic - Power

Detailed plan

Grade level - 6

Group category - small group

Content objectives

The children will

define the term power as the amount of work done divided by the time it takes to do the work;

define watt as a unit of power equal to one joule of work done in one second;

define the term horsepower as a unit of measurement;

convert watts to horsepower.

Skill objectives

The children will

measure force, distance, and time in order to calculate power;

manipulate the variable of time to denote the effect it has on power.

Materials

Flight of stairs

Meter stick

Scale (clinical or bathroom)

Stopwatch

Group Activity Sheet 5

Power

Problem(s) - 1. Find out what power means in scientific terms.

2. Find out how much power you use when you do work.

Background

1. From the last activity, we found a way of measuring work and expressed it in this way—work = force x distance (w = f x d)
2. This investigation adds one more variable to measure—**time**.
3. When the **rate** of work being done is known, the amount of power can be calculated.

$$\text{Power} = \frac{\text{force x distance}}{\text{time}} = \frac{\text{work}}{\text{time}} \quad (P = \frac{w}{t})$$

4. Power is also measured in watts. $1 \frac{\text{joule}}{\text{sec.}} = 1$ watt
5. Power is also measured as horsepower. 1 horsepower = 746 watts.

Review - Each member of this scientific team should complete this problem to review what you need to know to do today's activity:

You carried 3 kgms. of bricks a distance of 20 meters. How much work did you do?
Hint: force = kgms. x 9.8 - newtons.

Procedure - Today your group will collect data in teams of two. One scientist will keep time while the other scientists does work.

1. Measure and record the height of the flight of stairs by measuring the height of a single step and multiplying that distance by the total number of steps.
2. Read and record the weight of the scientists who will do the work.
3. Clock the time it takes for the scientist who was weighed to walk up the stairs.
4. Repeat step 3, only this time jog up the stairs.

Observations and conclusions

1. Calculate work for step 3 and step 4

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2. Calculate power for **step** 3 and **step** 4 (express your answers in joules/second)

3. Convert your answers for step 2 to **watts** (hint: see Background)

4. How much **horsepower** did it take to walk up the stairs? (hint: see Background)

5. How much horsepower did it take to run up the stairs?

Energy

Topic - Kinetic and potential energy

Detailed plan

Grade level - 5

Group - small group

Content objectives

The children will

use examples to explain the difference between potential and kinetic energy;

compare and contrast kinetic and potential energy;

demonstrate how one form of energy can be changed into another form.

Skill objectives

The children will

observe the conversion of potential energy to kinetic energy;

classify various examples as exhibiting kinetic energy or potential energy;

predict changes in the kinetic energy - potential energy relationship as an object changes its position.

Materials

Pendulum frame

Bob

String

Group Activity Sheet 6

Topic - Energy: Kinetic or Potential?

Problem(s) 1. Find out what the difference is between kinetic energy and potential energy.

2. Determine if an object is displaying potential energy or kinetic energy or both.

Background - Remember that energy is closely related to work. There are many different forms of energy—heat, light, sound, electricity, nuclear, chemical and others. Scientists generally divide these forms of energy into two groups, potential and kinetic.

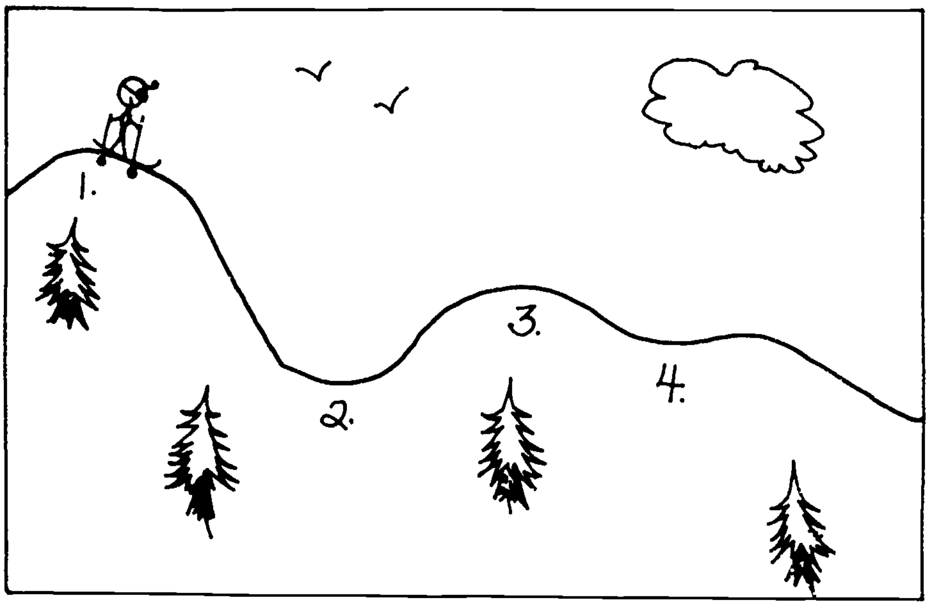
Procedure - Today your scientific team will use a pendulum setup and an illustration to investigate the relationship between potential energy and kinetic energy.

1. Set up your pendulum according to instructions.

2. Let the bob rest freely at the end of the string. Does the bob contain energy?
3. Raise the bob sideways to a position that will permit it to swing freely if released. Was work done as you raised the bob?
4. As you hold the bob in the higher position, does it contain energy?
5. If it contains energy, does it contain more or less energy than it did while resting freely? Why?
6. Release the bob permitting it to swing freely. Does it contain energy now? Why?
7. Repeat your experiment with the pendulum once more and discuss your group findings.
8. Now, read Supplement 1.

Conclusions

9. Based on this new information, were your answers in 2 through 6 correct? If not, repeat the experiment and review your findings.
10. For question 2, did the bob contain potential energy or kinetic energy? Why?
11. For question 6, did the bob contain potential energy or kinetic energy? Why?
12. Review your answers for questions 4 and 5. What **force** caused an increase in the potential energy of the bob while in the higher position?
13. Complete the following exercise. For each item on the list, put **P** for examples of potential energy, and **K** for examples of kinetic energy.
    a. a book on a shelf
    b. a can of gasoline
    c. a moving car
    d. a stick of dynamite
    e. a flowing river
    f. water behind a dam
    g. wind
    h. an avalanche
    i. stretched bowstring
    j. an idling automobile engine



14. In the illustration you see a person skiing down a slope. Using the numbered positions, answer the following questions.
    a. At what position will the skier have the greatest kinetic energy?
    b. At what position will the skier have the greatest potential energy?
    c. At what position will the skier have the least potential energy?
    d. As potential energy (increases, decreases), kinetic energy (increases, decreases).

Supplement 1

Kinetic energy

All moving things have the ability to do work. The snow in a snowslide can knock down trees and crush houses. A falling tree branch can knock a hole in a roof or break a window. In these examples, the snow and the branch are moving. Moving things have a kind of energy called kinetic energy.

Think of other things that have kinetic energy. A moving car has kinetic energy. A moving car might do work in knocking over a lamppost. When you throw a baseball, the ball has kinetic energy. If the ball is thrown at something like a can or a bottle, the ball can do work knocking it over. Heavy iron balls on chains are used to knock down old buildings. An iron ball is made to swing against the walls of a building. While the iron ball is swinging, it has kinetic energy.

Potential energy

Can things that are not moving have energy too? Even when they aren't moving, some things have the ability to do work. Their energy is stored. Stored energy is called potential energy.

Water behind a dam and a rock on the edge of a cliff have potential energy. Water behind a dam is higher than the water below the dam. If the water is allowed to flow down through the dam, it can do work turning a waterwheel. A rock on the edge of a cliff can also do work if it falls. It may hit other rocks or trees and make them move.

A stretched rubber band also has potential energy. If the rubber band is let go, it will snap back to its usual shape. While it is moving, it can do work pushing a small object forward.

Changes in potential energy

One way to understand potential and kinetic energy better is to examine some more examples of these forms of energy. Think about a arrow being fitted against the bowstring of a bow. Then the bowstring is pulled back and held. Before the bowstring is let go, the bow and bowstring have potential energy. When the bowstring is let go, the arrow is pushed for a short distance by the moving bowstring. Since the push is a force and the arrow moves some distance, work is done on the arrow.

When the bowstring is let go, its potential energy is changed into the kinetic energy of the moving arrow. But how did the bowstring get potential energy? Someone had to do work to pull the bowstring back. Energy was put into the bow and the bowstring by someone doing work. Pulling back the bowstring increases the potential energy of the bow and the bowstring.

In this example, you should have noticed two important facts. (1) Work must be done on an object to increase its potential energy. (2) Potential energy can be changed into kinetic energy (Blecha, Fisk, Holly, 1976).

Skeletal Plans

This instruction on the concepts of kinetic and potential energy can be augmented and extended by providing instruction which focuses on the following objectives.

1. Find the quantity of kinetic energy given to an object from the amount of work performed on the object.
2. Find the amount of potential energy stored in compressed springs and in elevated objects.
3. Solve word problems involving colliding or falling bodies, using the law of conservation of energy.

Energy – Plan 2

Esler and Esler (1981) describe four modes of operation for providing individualized instruction in science.

1. The systems approach
2. The open classroom
3. Enrichment learning centers
4. Inquiry centers

The following detailed lesson plans are designed to provide problem-solving opportunities and are based on a systems approach program. In order to create the materials for a systems approach unit, the following five-step process for teachers is recommended.

1. Determine learning objectives.
2. Structure activity sheets or cards for use by the individual child.
3. Set evaluation procedures.
4. Create an individual inventory of the unit's learning activities.
5. Gather appropriate materials for the prescribed learning activities.

The reader is strongly urged to become familiar with the reference cited here (i.e., Esler and Esler, 1981) for detailed information related to all areas of the systems approach mode.

Topic - Force

Detailed plan

Grade level - 5, 6

Group category - individual study

Content objectives

The children will

define force as that which can change the state of rest or motion of a body; a push or pull;

recognize friction as a common expression of force;

compare the effects of friction on the force required to move an object;

recognize gravity as a common expression of force.

Skill objectives

The children will

measure the force required to move an object at rest by exerting a pull;

Given a set of conditions pertinent to the effects of friction on two identical objects, make an inference to accommodate the observable outcome;

measure the effects of gravity on the acceleration of an object;

interpret data collected from measuring the effects of gravity on the acceleration of an object.

Materials

Metric ruler

Marble

Spring scale (force gauge)

Rubber band or string

Paper clips

Three standard-sized sheets of sandpaper

Stop watch (or clock with second sweep)

Student Activity Sheet 1

Topic - An introduction to FORCE

You will need a metric ruler, one marble, a stop watch, two small blocks (one centimeter thick each).
What to do.

1. Put a one centimeter block on the table top. Position your ruler so that one end will rest on the block and the other end is on the table top.
2. Starting at the very top of the ruler, roll a marble down the groove.
3. How far did the marble roll in two seconds?
4. Repeat this procedure two more times.
5. What was the average distance the marble rolled in two seconds? (Show your calculations.)
6. Repeat step 1, but raise the end of the ruler to two centimeters.
7. Repeat steps 2, 3 and 4 above.
8. What was the average distance the marble moved in two seconds using a height of two centimeters?
9. How does your data for step 8 compare with the data you recorded for step 5?
10. Read Supplement 1.
11. What force do you think was acting on the marble?
12. Why was the force greater when one end of the ruler was raised to two centimeters?

This activity sheet has been completed. Return all materials to control supply.

Now check your answers with the answer sheet for Activity 1. Put a check mark in the proper space on your progress sheet for each correct answer.

Take an activity sheet from the file marked **Force - Activity Folder 2.**

Supplement 1

There are many kinds of forces. The easiest examples of forces to understand are those in which you can actually see something pushing or pulling something else. Think of a baseball hitting a catcher's mitt, or a bowling ball hitting the pins. You can see the baseball push the mitt and the bowling ball push the pins. You can see the mitt and the pins move. Objects can also exert pulling forces. When a cowhand ropes a running steer, the steer pulls against the rope. Meanwhile, the cowhand and horse are pulling on the other end of the rope in the opposite direction.

It is easy to imagine the forces discussed above because you can see that they cause things to move. But what about an object that does not move when you push against it? Is there a force acting upon the object? There may not appear to be any, but the forces are there.

Friction is a common force. Suppose you put a cardboard box on the gym floor and give it a push. You apply a force to the box and the box slides across the floor. What happens to the sliding box? Will it keep on sliding forever? Of course not. You know from experience that the box will come to stop. Again, your experience tells you that friction caused the box to slow down and stop. Resistance to motion, caused by one surface rubbing against another, is called friction.

Friction is also affected by the smoothness of the sliding surfaces. If the surfaces are polished, the object will slide with less friction. For instances, a playground sliding board has a very smooth surface so that children can slide down easily.

Gravity is another common force. You know that when a ball is thrown straight up in the air, it does not keep going up forever. It stops and comes back down again. Think about the up and down motion of the ball carefully. You applied a pushing force in an upward direction to start the ball moving. What force slowed and stopped the ball's upward movement? Then, what caused the ball to come back down? The force that caused these actions is the force of gravity. It is the force of earth's gravity pulling on objects at or near the earth's surface that gives the objects the feeling we call weight (Tracy, Tropp, Friedl, 1979).

Skeletal Plan

The Systems Approach to individualizing instruction in science was developed to provide instruction towards the mastery of Content Objectives 1 and 4, and Skill Objectives 3 and 4.

You may develop your skills in providing science instruction for individual study as follows.

1. Let Content Objectives 1, 2, and 3 and Skill Objectives 1 and 2 serve as the basis for your instruction.
2. If you choose to use materials listed here, the activities associated with your instruction may be derived by inference.
3. Develop Student Activity Sheet 2 using the model shown herein.

Energy

Temperature and Heat

Detailed plan

Grade level - 8

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Group category - individual study

Content objectives

The children will

demonstrate the difference between heat and temperature;

name two commonly used temperature scales and tell how they differ;

describe how temperature is measured;

name two different units of heat, and explain how they differ;

describe how heat is measured.

Skill objectives

The children will

measure temperature with two types of thermometers;

experiment to determine the effects of heat on water (standard matter);

operationally define calorie;

make inferences regarding the effects of heat;

graphically illustrate the transfer of heat and its effect on temperature.

Materials

Three 500 ml graduated beakers

Water

Bunsen burner, ring, ring stand

Celcius Thermometer

Ice cubes

Graph paper

Bundle of nails

Tongs

Student Activity Sheet 3

Topic - Heat and Temperature

You will need three 500 ml. beakers, water, ice cubes, Bunsen burner and ring stand setup, thermomete bundle of nails, tongs.

What to do.

1. Fill one beaker about 3/4's full with ice and water. Put exactly 200 mls. of water in one beaker and he over a moderate flame until small bubbles start to appear. **Do not boil.** Turn off your burner.
2. Carefully pour 100 mils. of cold water (no ice) into one beaker. Place your thermometer in the co water. Wait until the liquid in thermometer stops moving.
3. What is the temperature of the cold water?
4. Repeat step 2 above using your hot water.
5. What is the temperature of the hot water?
6. Can you predict what the temperature would be if you mixed the hot water and cold water together?
7. Test your prediction.
8. Have you measured **heat** or **temperature** or both?

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9. Stop at this point and read Supplement 1.
10. Was your answer for 8 correct?
11. Let's begin again. Put a bundle of nails in a beaker of water. Put this beaker over a flame and bring the water to a slow boil for five minutes. Turn off your burner.
12. Put exactly 400 mls. of water (room temperature) in a beaker and set it aside. Read and record the temperature.
13. Using tongs (BE CAREFUL), put the bundle of nails in the beaker described in 12.
14. Read and record the temperature every 30 seconds for five minutes and graph your data.
15. How many calories of heat were transferred from the nails to the water in one minute? (Hint: reread Supplement 1 - temperature change x mass of water = amount of heat).
16. How many calories of heat were transferred in two minutes? Four minutes?
17. Can you think of a way to predict how much heat would be transferred from the nails to the water in eight minutes? Discuss your hypothesis with your teacher.

THIS ACTIVITY SHEET HAS BEEN COMPLETED. RETURN ALL MATERIALS TO CENTRAL SUPPLY.

Now check your answers with the answer sheet for Activity Sheet 3. Discuss your answers with your teacher before you proceed.

With teacher permission, take an activity sheet from the file marked HEAT AND TEMPERATURE - ACTIVITY FOLDER 4.

Supplement 1

Are heat and temperature the same?

You probably use the words heat and temperature every day. For example, you may talk about heating some food or heating your home. You may talk about the temperature in your home or outdoors. But just what do the words heat and temperature mean to scientists?

Perhaps you have seen steam pushing up the lid of a pot. In pushing the lid, the steam is doing work. The steam is able to do work because it is hot. In other words, heat causes the steam to do work. So heat is a form of energy.

Temperature is not the same as heat. However, temperature is related to heat. If matter gains heat, its temperature rises. If the matter loses heat, its temperature falls. So a change in the amount of heat in matter causes a change in temperature. Temperature, in a way, indicates the amount of heat present in matter. The higher the temperature of a piece of matter, the more heat there is in that piece of matter.

Measuring temperature

Heat is measured by measuring changes in temperature. Temperature is measured in units called degrees. The instrument used to measure temperature is a thermometer. The scale you probably use most often is the Fahrenheit scale. According to this scale, water boils at a temperature of 212 degrees at sea level and freezes at a temperature of 32 degrees.

Most scientists use the Celsius scale. According to this scale, water boils at 100 degrees at sea level and freezes at zero degrees. So a temperature change of one Celsius degree is greater than a temperature change of one Fahrenheit degree.

Measuring heat

Since temperature and heat are not the same, they are measured in different ways. Temperature is measured in either Celsius degrees or Fahrenheit degrees. Heat is also measured using two different units. One unit for measuring heat is the calorie. One calorie is the amount of heat that will raise the temperature of one gram of water one degree Celsius.

Another unit for measuring heat is the British thermal unit, or Btu. One Btu is the amount of heat that will raise the temperature of one pound of water one degree Fahrenheit. One Btu is about 250 times as much heat as one calorie (Blecha, Fisk, Holly, 1976).

Skeletal Plan

The Systems Approach to individualizing instruction in science was developed to provide instruction towards the mastery of Content Objectives 1, 3, and 5 and Skill Objectives 1, 2, 3, 4 and 5.

You may develop your skills in providing science instruction for individual study as follows.

1. Let Content Objectives 2 and 4, and question 17 from Student Activity Sheet 3 serve as the basis for your instruction. (Several skill objectives can be developed from question 17 as desired student outcomes.)
2. Identify all materials necessary for your instruction.
3. Develop Student Activity Sheet 4 using the model herein.

References

Blecha, M. K., Fisk, F. G., and Holly, J. C. *Exploring Matter and Energy*. River Forest, Illinois: Laidlaw Brothers, 1976.

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Tracy, G. R., Tropp, H. E., and Friedl, Alfred E. *Modern Physical Science*. New York: Holt, Rinehart, and Winston, 1979.

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Discovery Inquiry

These physical science laboratory lessons can be used with problem-solving techniques. Careful teacher preparation is necessary. The teacher's attitude toward any lesson is most important to its success.

These activities are miniatures of what great scientists have discovered after many years of pondering the evidence. Middle school youngsters discover basically the same principles in a much shorter time period. The teacher must feel confident that a given experience will generate enough data for a student to draw a conclusion consistent with the data. The teacher must understand that variance in data can and will occur; conclusions can vary from the absolute value. The teacher should be prepared to accept differences and not act as a verifier. Students not accustomed to problem solving techniques will continuously appeal for the teachers' opinion. It is up to the teacher to provide encouragement and stem frustration. But it is more important for the teacher to say, "If your conclusion is consistent with the data, then you must be correct," (or words to that effect), than to say, "You're wrong."

Each of the 12 problem solving activities is accompanied by notes to teachers explaining the posture they should assume for this particular lesson. Suggestions are also made concerning supplies and techniques.

One final word. The key to problem solving is the emphasis on process. Process alone, of course, is not all there is to "sciencing," but without the process students become automatons. The teacher will learn to feel comfortable in this setting when it is acknowledged that students will learn best if they are involved in doing and solving. If the teacher provides all the information, then the better students will stop there and go no farther and other students may not even try. The teacher should evaluate these activities in terms of the process first and content second. If the youngsters realize the teacher tests only on content the value of the process will be lost.

Sequence Diagram

Matter

Target Size	Detailed	Skeletal
Class	Physical and chemical change	Specific gravity
	Properties of acids and bases	Mystery liquids (Acid and base) X and Y
Small group	Introduction to elements and chemical formulae	Surface features of the moon
	How can physical properties help us?	Guess what it is?
Individual	Classification of elements	Moon's craters
	Separation of solutes	How much cargo can your boat hold?

Notes To Teachers

Physical and chemical change

It is important that the conclusions drawn be working definitions based only on students observations. The recitation following the self-quiz should reveal through discussion whether the objective was met.

Introduction to elements and chemical formulae

Competition among small groups will be keen. Some groups will devise a shorthand system of notation similar to chemical symbols. This should be encouraged.

Classification of elements

Each student receives the necessary 3 x 5 cards in order to develop his own coding system to enter data. Each organizational pattern is acceptable if it uses the data provided. Eventually the key organizational pattern will be two dimensional; that is, horizontal and vertical simultaneously. The error of oxygen may be frustrating to some; it is acceptable to tell those few the error. However, if the youngsters are confident in their organizational pattern, then oxygen is in the "wrong" place and they will challenge the printed word. (Individual) (detailed).

Separation of solutes

This problem solving activity may be done on paper or with materials. The teacher may ask for one first, then the other. Various properties of solutions should have been taught prior to this activity. (Individual) (detailed)

Properties of acids and bases

Each of the eight solutions should be no stronger than 0.5 molar. The teacher should choose familiar household acids and bases. After discussion the teacher can simply identify the liquids and assign the names and formulas. (Class size) (detailed)

Mystery liquids X and Y

Based on the activity "Properties of acids and bases," small groups of students will classify the two mystery liquids into either an acid or base depending on properties of the liquids. (Small groups) (skeletal)

How can physical properties help us?

This activity is designed for students to produce a complete list of physical properties that will identify an object. Using the guidelines and discussion mentioned in the activity involves a process as important as the product. The list should be extensive enough so that when the students pick an object the completion of the chart should accurately identify the object. (Small group) (detailed)

Guess what it is?

This activity will use the chart the groups have constructed in "How can physical properties help us?" They are each to select an object and describe it according to the list of properties they have developed. If the list has met the criteria for accuracy, then the students should guess correctly over 90 percent of the time. (Small group) (skeletal)

Specific gravity

Prior to this activity the students should have had laboratory experiences that insure competency in density. The students should be familiar with the facts (1) that density is a measure of compactness; (2) that it is determined by dividing mass by volume; (3) that it is measured in gms/cc; (4) that it is constant for a given material. The students should receive three or more materials, find the density and compare it to that of water. They should be able to predict that a specific gravity of greater than one will cause an object to sink, and that a specific gravity less than one will cause an object to float. (Class size) (skeletal)

How much cargo can your clay boat carry?

This activity is related to the "Specific gravity" lesson. The students should be given 100 g. of plasticene clay and determine its specific gravity. They should then form the clay into a boat, so that it floats. Now, ask them to compute the specific gravity. Next, give out uniform weights and ask the students to add "cargo" until the boat sinks. Compute which student's boat held the most cargo without sinking. Present the annual Archimedes Award. (Individual) (skeletal)

Surface features of the moon

There are numerous photographs of the moon's surface (close-up and distance) that are readily available. The youngsters should develop **any** ideas of the formation of the moon's features. The students in a small group should be allowed to test their ideas using kaolin or flour. They may need small lengths of tubing or hose, marbles, rocks, etc. This is a messy laboratory activity but well worth the bother. The students are being asked to test their hypotheses and discuss their value within a small group. This combination of processes is important in the development of their problem solving skills. (Small group) (skeletal)

Moon's craters

This activity may be most frustrating to the student. He may toss marbles at various angles and yet still come up with circular patterns. The formulation of theory is the key process in this activity. (Individual) (skeletal)

Physical And Chemical Changes

Class Activity

Problem When an object is changed can you predict if the change was physical or chemical?

Objective Given several structured mini-experiments the student will be able to predict a given change as either physical or chemical.

Physical Change

Materials

Wood block

Sandpaper

Ice

Sodium chloride

50 ml beaker

Glass slide

Goggles

Procedure

Do the following mini-experiments. Record your observation in the chart.

a. Put a small piece of ice on the lab table and allow it to remain there for 15 minutes.

b. Rub the sandpaper and wood together; examine before and after.

c. Dissolve one small scoop of sodium chloride in 50 ml of water in a beaker. Drop two drops of the mixture on a glass slide and dry it by **carefully** passing the slide back and forth through a bunsen burner flame. Wear goggles. Again, be careful of your fingers.

	Physical properties before	Physical properties after	Permanent or temporary change
Salt			
Ice			
Wood			

Conclusion

Make a general statement about the characteristics of a physical change.

Chemical Change

Materials

Watch glass

Sodium bicarbonate

Acetic acid (dropping bottle)

Phenolphthalein (dropping bottle)

Sodium hydroxide 1 percent

Marble chips

Hydrochloric acid 2 per cent

Sodium chloride

Lead nitrate (dropping bottle)

Procedure

Complete the following. Record your observations after each procedure in the chart. Keep your goggles on throughout class!!!

a. Place four drops of acetic acid CH_3COOH on a watch glass containing one scoop of sodium bicarbonate $NaHCO_3$.

b. Place four drops of phenolphthalein in a test tube containing 10 milliliter sodium hydroxide NaOH.

c. Place four marble chips in a flask containing 10 milliliter hydrochloric acid HCl.

d. Completely dissolve two scoops of salt NaCl in five or 10 milliliter water in a test tube. Add two drops lead nitrate $PbNO_3$ solution.

Observations

	Physical properties before	Physical properties after	Permanent or temporary change
Acetic acid + sodium bicarbonate			
Phenolphthalein + sodium hydroxide			
Marble chips + hydrochloric acid			
Lead nitrate + sodium chloride			

Conclusion

Make a general statement about the characteristics of chemical change.

Self-quiz to test your understanding

Classify each of the following as a Physical change **P** or Chemical change **C**.

1. An egg is boiled.
2. Salt is dissolved.
3. Wood is burned.
4. Water is evaporated.
5. Paper is torn.

Notes

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Introduction To Elements And Chemical Formulae

Small Group Activity

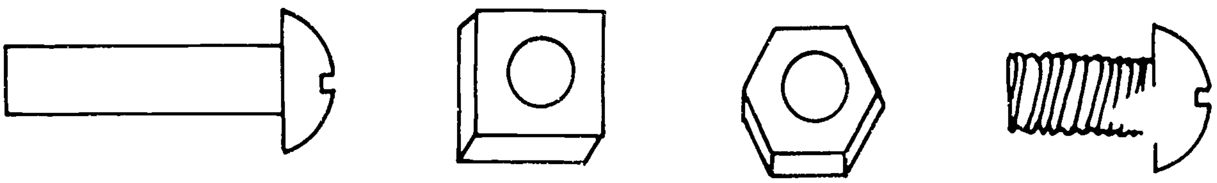
Scientists have studied many thousands of substances. From those studies they have come to a startling conclusion. There appear to be less than a hundred materials that can't be broken down into other substances!

Nothing has yet been found that is not a combination of two or more of these hundred basic building blocks—or, as they are called, elements. Trees, dogs, bananas, frogs, rocks, cars, books, even people—every kind of matter turns out to be made up of these elements. We call these elements "atoms."

Is it reasonable to think that the millions of kinds of matter in the world are made up of various combinations of less than one hundred kinds of atoms? Can such a small number of atoms really form that many combinations?

One can learn if this is a reasonable idea by using some common objects—nuts and bolts. Let the nuts and bolts represent different kinds of atoms. Find out how many combinations these nut atoms and bolt atoms can make. To keep the problem simple, work with only two different kinds of nuts and two different kinds of bolts. Four kinds of atoms.

The object of the game is to see who can make the largest number of different combinations using the nut and bolt atoms. Work in groups of two students each.



LONG BOLT SQUARE NUT HEX NUT SHORT BOLT

In the first round each team will use two short-bolt atoms and four square-nut atoms. The object is to see who can find the most ways of combining (hooking together) these atoms in a certain amount of time.

Rules

1. Two or more atoms (nuts and bolts) joined together by the thread on the bolts will be accepted as a combination.
2. If you use the same kind and number of nuts and bolts and thus get the same thing, it isn't a new combination.
3. Be sure you can make a combination before you draw it.
4. Once a combination is made and drawn, you can take it apart to make another. But you must be able to reproduce a combination you have drawn.
5. Make your drawings simple. For example, two combinations can be drawn like this:

You have five minutes to work on round one. Ready, set . . . . . . GO!

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Round 1 Combination

How many different combinations did you make in this round?

How many different combinations did your opponent make in this round?

Did anyone make any kinds of combinations you didn't think of?

Now for round two. This time you and your opponent will use five long-bolt atoms, five short-bolt atoms, 12 hex-nut atoms and 12 square-nut atoms. The rules for this round are the same as before.

Round 2 Combinations

How many different combinations did you make this round?

From this experience with nuts and bolts, write a short paragraph describing how all the world's matter can be formed from only 93 kinds of atoms.

Topic Classification of Elements

Objective After studying various organizational patterns a sequence will emerge that will be a predictor of behavior.

Below you will find a listing of 20 chemical elements. Using the information given, arrange these elements in some logical grouping.

Element	Symbol	Description
1. Aluminum	Al	Silvery metal
2. Argon	Ar	Colorless gas
3. Beryllium	Be	Silvery metal
4. Boron	B	Brownish crystal
5. Calcium	Ca	Silvery metal
6. Carbon	C	Black crystal
7. Chlorine	Cl	Green gas
8. Flourine	F	Yellow gas
9. Helium	He	Colorless gas
10. Hydrogen	H	Colorless gas
11. Lithium	Li	Silvery metal
12. Magnesium	Mg	Silvery metal
13. Neon	Ne	Colorless gas
14. Nitrogen	N	Colorless gas
15. Oxygen	O	Colorless gas
16. Phosphorus	P	Red or white crystal
17. Potassium	K	Silvery metal
18. Silicon	Si	Silvery crystal
19. Sodium	Na	Silvery metal
20. Sulfur	S	Yellow crystal

Questions 1. What reason or reasons can you give for grouping the elements as you have?

Questions 2. Does your grouping give any indication of the chemical behavior of these elements? Explain.

Using the new information given, find a new way of arranging the 20 elements.

Elements	Symbol	Description	Atomic Number
1. Aluminum	Al	Silvery metal	13
2. Argon	Ar	Colorless gas	18
3. Beryllium	Be	Silvery metal	4
4. Boron	B	Brownish crystal	5
5. Calcium	Ca	Silvery metal	20
6. Carbon	C	Black crystal	6
7. Chlorine	Cl	Green gas	17
8. Flourine	F	Yellow gas	9
9. Helium	He	Colorless gas	2
10. Hydrogen	H	Colorless gas	1
11. Lithium	Li	Silvery metal	3
12. Magnesium	Mg	Silvery metal	12
13. Neon	Ne	Colorless gas	10
14. Nitrogen	N	Colorless gas	7
15. Oxygen	O	Colorless gas	8
16. Phosphorus	P	Red or white crystal	15
17. Potassium	K	Silvery metal	19
18. Silicon	Si	Silvery crystal	14
19. Sodium	Na	Silvery metal	11
20. Sulfur	S	Yellow crystal	16

Question Does your grouping give any indication of the chemical behavior of those elements? Explain.

Having been given one more bit of information about these elements can you regroup them once again?

Element	Symbol	Description	Atomic Number	Number of electrons gained or lost in a reaction with other elements or compounds
1. Aluminum	Al	Silvery metal	13	3 lost
2. Argon	Ar	Colorless gas	18	0 lost or gained
3. Beryllium	Be	Silvery metal	4	2 lost
4. Boron	B	Brownish crystal	5	3 lost
5. Calcium	Ca	Silvery metal	20	2 lost
6. Carbon	C	Black crystal	6	4 lost or gained
7. Chlorine	Cl	Green gas	17	1 gained
8. Flourine	F	Yellow gas	9	1 gained
9. Helium	He	Colorless gas	2	0 lost or gained

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Element	Symbol	Description	Atomic Number	Number of electrons gained or lost in a reaction with other elements or compounds
10. Hydrogen	H	Colorless gas	1	1 lost
11. Lithium	Li	Silvery metal	3	1 lost
12. Magnesium	Mg	Silvery metal	12	2 lost
13. Neon	Ne	Colorless gas	10	0 lost or gained
14. Nitrogen	N	Colorless gas	7	3 gained
15. Oxygen	O	Colorless gas	8	2 lost
16. Phosphorus	P	Red or white crystals	15	3 gained
17. Potassium	K	Silvery metal	19	1 lost
18. Silicon	Si	Silvery crystal	14	4 lost or gained
19. Sodium	Na	Silvery metal	11	1 lost
20. Sulfur	S	Silvery crystal	16	2 gained

Question 1. What does your grouping now indicate about the chemical behavior of these elements? Explain.

2. One of the entries in the last column is a mistake! Can you find it?

Separation Of Solutes

Individual Activity

Objective After studying the solubility chart a student will be able effectively to write the procedures necessary to separate the powders.

Separation of Solutes

Imagine you have a mixture of three solids, sodium sulfate (Na_2SO_4), calcium carbonate ($CaCO_3$) and naphthalene (mothflakes). These substances consist of white particles, so they cannot be separated by sight. Use the solubility information in the table below to design a procedure for separating the substances. Your results should be three separate amounts of dry white solid.

Write your procedure---step by step---in the space provided.

Substance	Solubility	
	Water	Alcohol
Na_2SO_4	soluble	insoluble
$CaCO_3$	insoluble	insoluble
Naphthalene	insoluble	soluble

Procedure

Properties Of Acids And Bases

Class Activity

Objective After applying various tests to a number of liquids the student will be able to classify the liquids into two groups.

Properties of acids and bases

You will have available eight different liquids; carefully test each one in the following manner.

1. Test each solution with litmus paper; both blue and pink.
2. Place a tiny drop of each solution between forefinger and thumb. Rub.
3. Put five ml solution in a test tube, add a few drops of phenophthalein solution. Test each solution separately.
4. Add a small piece of magnesium ribbon. If in any case there is evidence of gas, test with a glowing splint.

Results

Solution	Blue litmus	Pink litmus	Touch	Phenophthalein	Magnesium ribbon	Name formula
A						
B						
C						
D						
E						
F						
G						
H						

Conclusion

1. Divide the solution into two groups with similar properties.
2. Enter the names and formulas for each solution after they are revealed by your teacher.
3. Summarize the properties of acids.
4. Summarize the properties of bases.

BONUS - Write chemical equations for the reaction between magnesium ribbon and each of the solutions.

Mystery Liquids

Skeletal Class Plan

Problem Can you properly group the two mystery liquids based upon tests you can perform?

Objective Given "Properties of acids and bases," the student will correctly group the mystery fluids as acids or bases.

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How Can Physical Properties Help Us?

Small Group Activity

Problem How can knowing about physical properties be useful?

Objective Students will devise a list of physical properties that will serve a useful purpose.

Discussion The term physical in this activity is meant to be anything we can measure or identify by our senses. That is, things we can measure, taste, feel, see, smell or hear. Properties are traits or characteristics that an object can posses.

Procedure

In your small group construct a chart that contains a list of physical properties.

Make sure in your discussion every member of your group understands the list. See if there are duplications.

Conclusion

When the list is complete, write all the uses a list of this kind could have for you.

Put the uses in practice; that is, see if the uses you listed really do work. Explain what your group did.

Guess What It Is?

Small Group Activity

Problem Can you identify an object based on its physical properties?

Objective Given the list of physical properties your group developed, guess the identity of an object. Record your results.

Specific Gravity

Class Activity

Problem What makes things float?

Objective Given a definition of specific gravity and a mini-experience, the student will be able to predict if an object will float or sink based on its value for specific gravity.

Discussion Probably some time in your life you have thrown an object into water and asked yourself if it would float. Because this is a very interesting and often asked question, scientists have studied why things float. Drop a coin into a beaker of water and then drop in a wood splint. Why does the wood splint float and the coin sink? Is it really because the coin is heavier? What if you put a rubber band around 500 wood splints, this would be heavier than the coin, but would it float? After you have successfully answered these questions you may go on to the next section.

Specific gravity is a term used by scientists. It is a number that tells if an object will float or sink in water. If an object has a specific gravity of more than one it will ______________________. (You find the answer.) The way of finding specific gravity is to divide the density of water into the density of the object. Be sure you test tap water for its density.

Problems Find the specific gravity of three items provided for you and then answer the question, Will it float?

$$\textbf{Density} = \frac{\textbf{Mass}}{\textbf{Volume}}$$

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How Much Cargo Can Your Boat Hold?

Individual Activity

Problem Make a boat out of the clay so that it holds the most cargo in your class without sinking. Try to win the great "ARCHIMEDES AWARD."

Procedure Ask your teacher for directions. Good luck.

Resources Modeling clay

Water in quantity enough to allow clay boats to be floated.

Surface Features Of The Moon

Small Group Activity

Problem Develop several ideas of how the features on the moon's surface were found?

Objectives Using a variety of photographs and mini-experiences the student will develop and test ideas concerning the formation of surface features found on the moon.

Discussion When you look at photographs of the moon, you will notice large craters, secondary craters, rills, rays, "seas" and mountains. Study the photos and with the use of materials try to develop ideas of how they are formed. Test your ideas. Draw your conclusions and discuss them within your group.

Resources NASA moon photographs

Moon's Craters

Individual Activity

Problem Why are the moon's craters circular?

Objective Given the experiences from "surface features of the moon," the student will experimentally analyze why the craters are circular.

Discussion Using any method you can develop, test, with your teacher's permission, a theory of why the craters of the moon are circular.

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Experimental Inquiry

This unit is designed for use with various instructional group sizes, including individuals. Class, group and individual activities are sequenced as indicated by placement from left to right in the unit plan. The activities suggested are not intended to be all-inclusive. The teacher is urged to be creative in substituting for or adding to these activities. The questions are designed to stimulate interest in and give structure to the unit.

It is the intent that all students participate in the class and group activities. Individual activities are to be done simultaneously with and in addition to the class and group activities. The individual activities are to permit students to proceed at a pace commensurate with their interest and ability and to allow choices in what they study and how they go about it. Results of these activities are to be shared with the total class for the enrichment of all.

Class sessions allow time for presentation of necessary background information, brainstorming ideas, reports of group and individual activities and for skill sessions. Students are to keep accurate records of experimental results, analysis of data and other pertinent information in their own notebooks. These notebooks should be considered as important as a textbook.

Evaluation is based on the degree of mastery of the unit objectives. Tasks are referenced to the objectives by a lower case letter in parenthesis following the task description.

TOPIC - The Molecular Transport and Exchange of Gases Within the Biosphere

Molecular Transport and Exchange of Gases Within Animals (3-4 Weeks)

Molecular Transport and Exchange of Gases Within Plants (2-3 Weeks)

Molecular Transport and Exchange of Gases Within Biosphere (3-4 Weeks)

Unit A

The Molecular Transport and Exchange of Gases Within Animals

Time 3-4 weeks

Equipment

OBJECTIVE

When you finish this unit you will understand the concept of molecular transport and the exchange of gases within animals.

You will know you are making progress toward meeting this objective when you can

a. measure, chart and graph increases in the pulse, heart and breathing rate and recovery time after exercise;

b. explain the cause of the pulse and why it increases with exercise;

c. identify the gases exchanged;

d. compare and contrast arteries and veins;

e. demonstrate the process of diffusion;

f. identify the major parts of the transport and exchange system and summarize their function;

g. recognize and describe the interactions and the interdependencies which occur during the molecular transport and exchange of gases and the equilibrium achieved within a living system.

How does exercise affect the pulse rate?

Tasks

Class	Small Group	Individual
Calculate class averages, ranges. Compare boys and girls. Answer question and make inferences. (a)	Plan action to answer question. Plan method of measurement and recording. Chart and graph pulse rate resting and after exercise and the recovery time. (a)	Measure, chart, graph resting and after exercise pulse rate and recovery time of a variety of groups — different ages, smokers versus nonsmokers, joggers, etc. Compare and infer relationships. (a)

What causes the pulse?

Tasks

Class	Small Group	Individual
Discuss three-chambered versus four-chambered hearts and the importance of the separation of oxygenated blood and deoxygenated blood. (f)	Pairs of students use stethoscopes to measure rate of heartbeat, resting and after exercise and recovery time. Chart, add to graph. Compare. (a)	Repeat above activity using stethoscope. (a)
Discussion of group results and observations. Compare data. Draw inferences. Answer question. (b)	Use **fresh** (if at all possible) or preserved hearts of frogs, pigs, sheep and cows to identify and compare the structure and function of the heart. Diagram and label. Record likenesses and differences.	Measure and compare heartbeat and pulse rate of animals (dogs, cats, birds.) Hypothesize reasons for differences. Gather data to check hypothesis.
	Note vessels attached to the hearts and record observed differences between arteries and veins. In which of these is the pulse felt? (b) (d) (f)	Gather information on congenital heart defects. (f)
	Fit a plastic squeeze bottle with a two-hole stopper and equal lengths of glass tubing and rubber tubing. Fill the bottle with water (colored red for realism) and squeeze. Measure and record the distance the water traveled for each tube. Compare to arteries and veins and their relative blood pressure. (d)	Investigate factors present in our way of life which lead to a high incidence of heart disease. (f)
	Examine a fish tail under a microscope. Observe arteries, veins and capillaries. Note direction of flow and the pulse. (b) (d) (f)	Prepare a short paper on why large organisms need a transportation system. Compare transportation systems. Compare transportation systems of simple organisms to that of complex organisms. (g)
		Study the effect of temperature and chemicals (alcohol, nicotine, aspirin) on the circulation of blood in a goldfish. (b) (e)
		Prepare blood slides. Stain and make microphotographs. (f)

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How does exercise affect the breathing rate?

Tasks

Class	Small Group	Individual
Answer question.	Use same method as before to measure, chart, and graph resting, after exercise and recovery time of breathing rate. Compare to pulse and heart beat data. (a)	Make the same measurements and comparisons as made in pulse and heartbeat investigations. Analyze data and make inferences. (a)
Discuss the interrelationships of pulse, heart beat and breathing.		
Recognize and describe the interactions within a living system. (a) (g)		

What gases are exchanged?

Tasks

Class	Small Group	Individual
Discuss answer to question and methods to verify answer (c)	Measure intake of oxygen in the lungs by comparison with the time a candle will burn in room air and in exhaled air. (c)	Analyze the effect of different types of smoke in insects, plants or small animals. Make inferences and relate to air pollution. (c)
Discuss group results and observations. Compare data. Interpret and answer question. (c)	Set up an apparatus to measure the differences in the amount of CO_2 in exhaled air and in inhaled air. (c)	Design an apparatus to "smoke" cigarettes. Compare levels of tar and nicotine. Gather information about relationship of smoking to disease and longevity. (c)
	Use cobalt chloride paper to observe water vapor present in inhaled air and exhaled air. (c)	Describe the effects of low and high pressure on breathing. What happens to a mountain climber? A diver? (c) (g)
	Breathe in and out of a paper bag held over nose and mouth so the same air is breathed over and over for several minutes. Explain results in terms of the exchange of gases in the bag. (c)	

Where are gases exchanged?

Tasks

Class	Small Group	Individual
Observe the **fresh** cardiovascular organs of a pig or cow. Note and touch bronchial tubes and bronchiole. Why are lungs spongy? Why pink? Infer location of the gaseous exchange. Identify pulmonary vessels. Build on observations to suggest answers to question. (f)	Use **fresh** (if at all possible) or preserved hearts of frogs, pigs, sheep and cows to identify and compare the structure and function of the heart.	Make a chest and heart model. (f)
Discuss three-chambered versus four-chambered hearts and the importance of the separation of oxygenated blood and deoxygenated blood. (f)	Diagram and label. Record likenesses and differences.	Gather information on congential heart defects. (f)
Demonstrate examples of diffusion and make an analogy to the exchange of gases within the body. (e)	Note vessels attached to the hearts and record observed differences between arteries and veins. In which of these is the pulse felt? (b) (d) (f)	Investigate factors present in our way of life which lead to a high incidence of heart disease. (f)
Present group reports to class. Interpret and infer an answer to question. Review all data and observations. Relate body function to body structure. Recognize and describe the interactions and the interdependencies which occur and the equilibrium achieved within a living system. (g)	Fit a plastic squeeze bottle with a two-hole stopper and equal lengths of glass tubing and rubber tubing. Fill the bottle with water (colored red for realism) and squeeze. Measure and record the distance the water traveled for each tube. Compare to arteries and veins and their relative blood pressure. (d)	Prepare a short paper on why large organisms need a transportation system. Compare transportational systems of simple organisms to those of complex organisms. (g)
	Examine a fish tail under a microscope. Observe arteries, veins and capillaries. Note direction of flow and the pulse. (b) (d) (f)	Study the effect of temperature and chemicals (alcohol, nicotine, aspirin) on the circulation of blood in goldfish. (b) (e)
	Measure lung capacity. Calculate the volume of air that passes through the lung per minute resting and after exercise. (a)	Prepare blood slides. Stain and make microphotographs. (f)

Use a balloon, purple cabbage leaf or other materials to observe diffusion of gas through a membrane. (e)

Measure lung capacities of various groups as before. Compare data and identify relationships. (a)

Explain why earthworms are found on the pavement after rain. Describe how various plants and animals exchange gases. Include micro-organisms. (e)

Describe the kind of respiratory system all living things have in common. (g)

Unit B

The Molecular Transport and Exchange of Gases Within Plants

Time 2-3 weeks

Equipment

Objectives

When you finish this unit, you will understand the concept of molecular transport and exchange of gases within plants.

You will know you are making progress toward meeting this objective when you can

a. recognize that the production of O_2 is an indicator of photosynthetic activity;

b. show by experimentation that CO_2 is necessary for photosynthesis to occur;

c. describe how water is involved in the photosynthetic process;

d. explain transpiration, root pressure and capillary action;

e. identify the major parts of the transport and exchange system of a plant and summarize their functions;

f. recognize and describe the interactions and the interdependencies which occur during the molecular transport and exchange of gases and the equilibrium achieved within a living system.

What gases are exchanged during photosynthesis?

Tasks

Class	**Small Group**	**Individual**
Clarify and define photosynthesis. Discuss procedures necessary to verify information and to answer question. (a) (b) (c)	Record and report all known information about photosynthesis. (a) (b) (c)	Find out how to use a greenhouse. How are materials provided that are essential for photosynthesis? Make a functioning mini-greenhouse. (a) (b) (c)
Compile group results. Verify information on use of CO_2 by plants and the production of O_2 and water vapor. Introduce and define transpiration. Answer questions. (a) (b) (c) (d)	Prepare two "starved" plants, one covered with source of CO_2 (HC1 and marble chips) and one with CO_2 removed (by lye). Place in light for two days. Test leaf from each for starch. Record results. How is this a test for use of CO_2? (b)	Make a model to investigate the relationship of surface area to the rate of transpiration. Graph results. Interpret. (d)
	Prepare two test-tubes of purple cabbage pieces. Add a pinch of sodium bicarbonate to each test-tube. Put a stalk of elodea in one test-tube. Set both test-tubes near the light. Which turns color? What causes color change? (b)	Experiment or gather information on the rate of transpiration in a variety of plants. (Include cacti). (d)
	Heat a jar of water to boiling to drive out gases. Cool and add 1/4 teaspoon baking soda to provide CO_2. Add elodea and cover with a funnel. Insert test-tube of water over funnel. Place in light. Collect gas and test with glowing splint. What is the gas? (a)	Experiment to determine factors that affect rates of transpiration (temperature, humidity, light). (d)
	Tie a plastic bag around the pot of a houseplant. Tie another plastic bag around the leaves and stem of the houseplant. Observe for several days. (c) Note formation of water drops.	

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How do gases enter and leave a plant?

Tasks

Class	Small Group	Individual
Through class discussion, hypothesize the need for an opening in the leaves (e)	Verify hypothesis by examining tear sections of lettuce, spinach, and other leaves under the microscope. Find, identify and draw guard cells and stomates. Compare the appearance and size of stomates in a well-watered plant and an unwatered plant. Infer function of guard cells and stomates. (e)	Make collodion casts of leaves and compare. Do cactus plants have stomates? Evergreen needles? Water plants?
Answer question.		Do stomates open and close with day and night? (e)
		Make a model cell. Show diffusion through the membrane. (e)

How are materials transported within a plant?

Tasks

Class	Small Group	Individual
Discuss results of activities. Define root pressure and capillary action and relate to transpiration. Answer question. (d)	Observe germinating seeds on moistened paper towels. Describe appearance and note root hairs. How does their structure provide for efficient absorption of water? (e)	Prepare an osmometer to show diffusion of water into a cell. How does this explain root pressure?
Pull all data together. Recognize and describe the interactions and interdependencies which occur during the molecular transport and exchange of gases and the equilibrium achieved within a living system. (f)	Use celery and colored water to observe use of water in conducting tissues of a plant. Measure the rate of rise. Record and graph. Repeat and add salt to colored water. Explain observations. (e)	Perform an experiment in an unused field to study the effect of table salt on weeds. (e)
	Stand glass tubing of different diameters in colored water. Record the effect of diameter on the height to which water rises inside the tube. (d) (e)	Prepare a collection of photomicrographs of plant parts. (e)
	Make thin sections or use prepared slides and observe and identify the phloem and xylem in the vascular bundles. (e)	
	Make a model or diagram of a whole plant showing the transportation and exchange of gases. (f)	

Unit C

Molecular Transport And Exchange Of Gases Within The Biosphere

Objectives

When you finish this unit you will understand the concept of molecular transport and exchange of gases within the biosphere.

You will know you are making progress meeting this objective when you can

a. explain the meaning of the term "biosphere";

b. diagram the carbon, oxygen, nitrogen and water cycles;

c. identify and describe the relationships observed in an outdoor area near your school;

d. describe man's influence on the biosphere;

e. recognize and describe the interactions and the interdependencies which occur during the molecular transport and exchange of gases and the equilibrium achieved within the biosphere.

Some Suggested Tasks

Class

1. Walk in the school area. Look for specific examples of relationships and interactions. Record. (c)
2. Compile a list of interactions observed among different organisms and their environment. Keep list posted, add to it as other observations are made. Use list to establish an understanding of the term "biosphere." (a)
3. Gather information on the causes of the extinction of some species of animals. (e)
4. Gather information on the effect alien species have on an established environment when introduced to it. (e)

Small Group

1. Establish a terrarium or an aquarium. Observe and record the interactions. (e)
2. Study the interactions of micro-organisms in pond, creek, or lake water. (e)
3. Gather data on the amount of carbon plants remove from the atmosphere yearly. Prepare a diagram showing how the carbon supply is replenished and held relatively constant. (b)
4. Prepare a diagram to show how oxygen is used over and over again. (b)

Individual

1. Compare mini-biospheres in fresh and in polluted water. (d)
2. Gather information on legislation on the city, state and national level governing the protection and the use of resources. (d)
3. Describe conditions that would be necessary on another planet for life to exist.
4. Investigate the effect of air pollution on respiratory disease. (d)

5. Make a study of your community. Consider population area, parks, schools, roads, waste disposal, housing. Note interrelationships among them. (e)

5. Investigate the relationships that produce the nitrogen cycle. Diagram. (b)

6. Examine roots of clover for nitrogen-fixing bacteria. (b)

7. Measure water needed for a shower, a tub bath, to flush a toilet, wash a car, etc. Estimate amount used in your house or school. Find out how water is recycled and diagram. (d)

5. Analyze a mini-community through the use of quadrats.

6. Investigate the effect the automobile has made on the environment.

7. Study the effect of the weakening of environmental contacts on the nation. (d)

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Appendix I

Essential Skills
Science

TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
Problem Solving	The learner will use process skills (observing, classifying, inferring, predicting, measuring, communicating, interpreting data, making operational definitions, formulating questions and formulating models) as a basis for solving problems.				10 12 19 14	1 10 11 15 16 17 18 19 20	4 5 9 10 11	2 3 7 8 10 11 12	4 8 9 10 13	2 5 6 14 16
Process of Science	The learner will									
1. Observing	a. make observations in a variety of ways using all of the senses;	I	D	D	14			2	10	16
	b. use indirect methods if direct sense experience is insufficient to observe objects or events;	I	D	D			11	8	13	16
	c. make quantitative observations to accumulate precise data;	I	D	D		16		11		5 6
2. Classifying	a. classify objects on the basis of observations;	I	D	D	14	1 10		3	8	14
	b. classify objects and events on observable similarities and differences of selected properties;	I	D	D	14	10			8	
	c. use classification keys to place items within a scheme or to to retrieve information from a scheme;		I	D	14	15		11	8	14
3. Inferring	a. make evaluation and judgments based on observation;	I	D	D	12 19	16	9 11	8 11	1 7 10	18
	b. formulate alternative explanations for observed events;	I	D	D			9 11	8 11	7 10	18
4. Predicting	a. propose an expected result based on past experience;	I	D	D		17	10	2 11	7	18
	b. make predictions based on observations of events;	I	D	D		17	10	11	8	17
	c. confirm a prediction through an experiment;						10		8	
5. Measuring	a. measure properties of objects or events by direct comparison using standardized units;	I	D	R		15		3 7 8		16 17

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TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
	b. combine fundamental units into other measurable dimensions such as density, pressure velocity, etc.;	I	D	D				8 11		
	c. make a statement about precision, accuracy and uncertainty;			I,D		17	11	12		21
6. Communicating	a. keep accurate records of observations for checking and rechecking by others;	I	D	D	10	11	4 5	10 12		14
	b. make graphic representations of accumulated records of observations and communicate this information clearly and meaningfully;	I	D	D		11	4 5	2	10	14 15
7. Interpreting data	a. use processes such as classifying, predicting, inferring and communicating to interpret data;	I	D	D	14	10	9	2	4	6
	b. revise interpretations of data based on new information or revised data;	I	D	D	19		9	8	4	6
8. Making operational definitions	a. describe limits of a system;	I	D	D		15 16	5	11	9	6
	b. describe the procedure used to measure the identified variable in this system;	I	D	D		15	5	11	9	6
	c. define operational definition as the process used to measure a dimension;									
9. Formulating questions and hypotheses	a. Form questions on the basis of observations;	I	D	D	12 19	17	9	9		16
	b. generate more questions or problems to be solved through application of other processes of science;	I	D	D	19		9	9		14 16
	c. devise a statement which can be tested by experiment;	I	D	D			9	12	10	6
10. Experimenting	a. consider conditions under which an hypothesis might be tested;	I	D	D		19	10	12	8	6 14
	b. identify variables and the control aspects of an experiment;		I	D		20	9 10	12	10	6 14
	c. design data-gathering procedures to test the hypothesis;	I	D	D				12	10 13	6 14
	d. consider limitations of methods and apparatus of experimentation;	I	D	D		17		12	10 13	6 14
11. Formulating models	a. devise models on the basis of acceptable hypothesis or hypotheses that have yet to be tested;		I	D	19	17		11	10 13	6 14
	b. use models to describe and explain interrelationships of ideas;	I	D	D		17		11	10 13	6 14
	c. account for limitations in accepted models.						9	11	10 13	6 14

TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
Matter	The learner will									
1. Description	a. describe surfaces by color, shape and texture;	I,D	R	R	14		2		3	
	b. differentiate among solids, liquids and gases;	I	D	R	14		2		3	
	c. classify similar objects by particle size;	I	D	R	14		2	7	9	
	d. explain the difference between mixtures and solutions;		I	D	14		5		3	16
	e. measure matter by both volume and mass;	I	D	R		15		3	3	16
	f. describe density as light or heavy;	I,D							3	
	g. predict ability of objects to float in water;	I	D				10		10	
	h. define density as mass per unit volume;		I	D		15			3	
	i. explain changes in matter (form or phase) requiring energy exchange (input or output);		I	D			9		8	
2. Structure	a. explain structure of matter as array of atomic building blocks;		I	D			9		3	
	b. describe crystal structure by shape;	I	D	D	14		9		3	15
	c. explain the physical properties of crystals;		I,D				9		3	
	d. classify matter according to theoretical structure, *e.g.*, ionic or covalent (electrical attraction or electron sharing);			I,D			9		3	
	e. describe the chemical atom as dense positive nucleus surrounded by negative electron cloud;			I,D			9		3	
	f. differentiate between living and nonliving matter;	I	D	R	14		9		3	
3. Earth-space relationships	a. describe earth as a sphere in space, part of solar planetary system;	I	I,D	R	14		9		3	
	b. describe the solar system in the context of its relative galactic position;		I	R			9		3	
	c. recognize sun as principal source of earth energy;	I	D	R	14		9		3	
	d. describe climatic zones of earth (polar, temperate, topic);	I	I,D	D	14		9		3	
	e. recognize atmosphere, lithosphere, hydrosphere as gaseous, solid and liquid components of earth structure;	I	D	R	19		1		8	
	f. classify rocks by their methods of formation (igneous, metamorphic, sedimentary);	I	D	R	19		9		8	
	g. show familiarity with theoretical structures of lithosphere (plate tectonics, mantle, and liquid core);		I	D			4		8	

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TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4 R	CRT-4 M	CRT-8 R	CRT-8 M	BASIC SKILLS R	BASIC SKILLS M
	h. test rocks and stones for color, hardness, crystal structure;	I	I,D	D	19		9		8	
	i. differentiate fossiliferous stones from igneous or metamorphic rocks;		I	I			9		8	
	j. explain water cycle and related weather phenomena;		I	D			9		8	
	k. relate tilt of polar axis to seasonal variations;		I	D			10		8	
	l. explain tidal behavior as earth-moon-sun gravitational coupling;		I,D	R			10		8	
	m. describe forces tending to change the earth's surface (water flow, air flow, vulcanism, humans);	I	I,D	D	19		10		8	
4. Water	a. show appreciation of water as unique substance essential to life functions and to many natural inorganic changes;	I	D	R	19		9		8 9	
	b. describe molecular structure of water;		I	D			9		8	
	c. explain weak polar electrical properties of water molecules;			I,D					8	
	d. explain the nature of aqueous solutions as either molecular or ionic;		I,D	D			9		8	
	e. classify acid-base water solutions by measuring with appropriate indicators;	I	I,D	D,R	14		11		9	
	f. describe acidity/basicity of water solutions as functions of hydrogen ion concentration (pH);		I	D			9		8	
5. Elements	a. differentiate among elements, compounds and mixtures;	I	D	R	19		9		8	
	b. show awareness of periodicity of elements by using the periodic table;	I	D	R			9		8	
	c. differentiate among metals and nonmetals;		I,D	I,D	19		9		8	
	d. classify elements by electron configuration;			I,D					8	
	e. explain peculiar properties of oxygen, hydrogen and carbon and their role in basic life processes;			I,D						
	f. using the periodic table, show awareness of molecular weight and use Avagadro's number to explain mole concept;		I	D					10	
	g. relate atomic number to proton number;			I,D					8	
6. Technology	a. identify and use simple machines;	I	D	R	10				3	
	b. predict changes of direction and intensity of forces using simple machines;		I,D	R			9	3	3	16 17

TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
	c. describe systems for converting energy or transferring information, interpreting such systems as planned uses of peculiar properties of certain types of matter such as fuel, engines, electricity generation, light generation, radio, television, computers;		I	I,D,R						
	d. show awareness of contribution of technology to our society.	I	D	D	14		9			
Energy	The learner will									
1. Force	a. identify a force as a push or pull;	I,D	D,R	R	10				16 17	
	b. measure forces with balances, springs and other appropriate devices;	I	D	D,R	19	15		3	16 17	
	c. describe methods for adding vector quantities;	I,D	D	R	19		9		8 9	
	d. identify and define in operational terms the three Newtonian laws of motion;						9		8	
	e. define inertia qualitatively as the resistance to change in motion;		I	D,R			9		8	
2. Distance	a. measure distance in appropriate standard or arbitrary units;	I	D	D,R		15		3		16 17
3. Energy	a. define energy as a cause for change;				19		9		9	
	b. qualitatively define potential energy;				19		9		9	
	c. qualitatively define kinetic energy;				19		9		9	
	d. define energy quantitatively as work equivalent;				19		9			
4. Time	a. develop ability to tell time;	I,D	R	R		15				
	b. measure time intervals using standard clock stopwatch;	I	D	D,R		15		3		16 17
5. Work	a. qualitatively describe work as energy expended;				19		9		9	
6. Power	a. make mathematical comparisons between force and distance and in forming an operational definition of power;		I	D		15	9	3		16 17
	b. define power as rate of doing work;		I	D	19		9		9	
7. Gravitation	a. identify gravity as force (pull);	I	D	R	19		9		9	
	b. measure gravitational attraction of earth (weight);	I	D	R		15	9	3		16 17
	c. identify gravitational attractions of celestial objects, planetary orbits;					15	9		9	
	d. calculate gravitational acceleration and quantify energy equivalents of mass times height;			I,D						16 17

TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
8. Energy conservation	a. identify examples of conservation of energy in mass-matter interchanges;		I	D			9		8	
	b. define conservation of energy as constancy of total energy both before and after any change within a system;		I	D			9		8	18
9. Chemical energy	a. describe and identify foods as sources of biochemical energy;	I	D	R	14		9		8	
	b. relate energy from food or fuel to making and breaking bonds between atoms;			I,D					8	
	c. describe the operation of electro-chemical battery (electric cell) as a chemical reaction involving a transfer of electrons;		I	D			9		8	1
	d. describe electrolysis;		I	D			9		8	
	e. use safe procedures in handling hazardous chemicals;	I	D	D	14		10		4	
10. Electromagnetic energy	a. perform simple demonstrations of static electricity using paper, plastic, rubber;	I	D							
	b. identify electrical forces of both attraction and repulsion;		I	D			9		8	
	c. recognize polarity of magnetic substances, predict attraction or repulsion based upon polar similarity or dissimilarity;	I	D		14		9			
	d. generate electrical energy with moving magnet and wire conductor;		I	D						
	e. measure electric variables with appropriate instrumentation;		I	D				3		17 18
	f. perform simple demonstrations of interaction among batteries, bulbs and wires;	I	D							
	g. construct electrical circuits and predict performance of variables as function of circuit design;		I	D				7		
	h. differentiate between direct and alternating current and predict energy transmission with each form of current;		I	I,D			9	7	8	
	i. describe electric power generating facilities as energy conversion devices;		I	I,D			9		8	
	j. describe electromagnetic spectrum as the organizing principle of radio, light, x-ray and other similar waves;		I	D			2		8	
11. Light energy	a. show that light can be produced from electrical or chemical energy;	I	D	R	12				8	
	b. explain light as a wave phenomenon;		I	D			2		8	

TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
	c. demonstrate light control using optical devices such as mirrors and lenses; predict effects of various optical devices;	I	D	D	19			8		18
	d. explain optical function of human eye, formation of camera image;	I	D				9			
	e. explain light propagation as particulate (photon) emission;			I I					8	
	f. identify colors;	I,D	R	R	19					
	g. differentiate between colors and pigments;		I	I,D					8	
	h. identify optical spectrum as small segment of electromagnetic spectrum;		I	D			9		8	
	i. relate color to frequency of radiation;			I					8	
12. Sound energy	a. describe sounds as low, high, quiet, loud, pleasant, harsh;	I	D	R	10		11		8	
	b. explain sound as compression wave phenomenon;		I	D			9		8	
	c. measure sound in terms of energy units;			I,D						18
	d. relate conversion of several energy forms - electrical, mechanical - into sound;	I	D	R	19		9		8	
	e. explain the mechanism of several sound devices such as ear, telephone, vocal cords, loudspeaker;		I	D			9		8	
13. Nuclear energy	a. describe atomic nuclear structure;						9		8	
	b. explain instability theory;								8	
	c. describe functioning of nuclear reactor, heat/ electricity generator;						9		8	
	d. recognize normal background radiation phenomenon;						9		8	
	e. demonstrate appropriate safety precautions for dealing with radioactive materials;								4	
	f. differentiate among nuclear radiation phenomena (alpha, beta, gamma radiation);						9	8	8	
	g. describe nuclear energy production as conversion of matter to energy;						9		8	
14 Heat energy	a. demonstrate heat as change agent (cooking, melting, reforming);	I	D	R				8		
	b. measure temperature;	I	D	R		16		7		17
	c. explain relationship of temperature to molecular motion;		I	D	19		9		8	
	d differentiate between heat and temperature;	I	D	R	19		9	11	8	

TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
	e. explain heat transfer mechanisms (convection, conduction, radiation);	I	D	R	19		9		8	
	f. demonstrate generation and loss of heat in mechanical energy exchanges.		I	D			9		8	
Interaction										
	The learner will									
1. Interdependence	a. identify evidences of interdependence in living systems;	I, D	D, R	R	19		9		8	
	b. identify evidences of interdependence within organisms;	I	D	R	19		9		8	
	c. draw inferences about interdependence based on field observations;		I, D	D,R			9		8	
	d. describe plant/plant, plant/animal, animal/animal interactions;	I	D, R	R	19		9		8	
	e. describe biogeochemical cycles;	I	D, R	D, R	19		9		8	
2. Heredity	a. describe structure and function of cellular compounds such as DNA and RNA;		I, D	D, R			9		8	
	b. explain the transfer of genetic information;		I	I, D, R			9	11	8	
	c. describe the inheritance of human traits with emphasis on heredity diseases;		I, D	D, R			9	11	8	
	d. explain heredity as the mode of species continuation;		I	D, R			9		8	
3. Environment	a. describe a comprehensive model of environmental interaction;	I	I, D	R	19		9		8	
	b. construct models for analysis of environmental problems;		I, D	D, R			9		8	
	c. recognize environmental impact on personal life;	I	D	R	19		9		8	
	d. manage personal environment in an effective manner;	I	I, D	D, R	19		9			6
	e. analyze systems in the environment in order to understand the holistic model;		I, D	D, R			9		8	
4. Change	a. describe change as a necessity for species survival;	I	D, R	R	19		9		8	
	b identify examples of change in macrosystems, among organ systems, organisms and ecological systems;	I, D	D, R	R	19	1	9		8	
	c. interpret change and equilibrium as a dynamic interaction;		I	D, R			9		8	
	d. measure and analyze changes in living systems;	I, D, R	D, R	R	19	17	9 10	8	8 9	15 18
5. Equilibrium	a. recognize and describe systems in equilibrium;		I	D, R			9 10		8 9	
	b. define equilibrium in living systems;		I, D	R			9		8	
	c. defend the concept of equilibrium by using models;		I	D, R				12	8	
	d. quantify equilibrium;			I, D					8 9	

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TOPIC	CONCEPT/SKILL	K-4	5-8	9-12	CRT-4		CRT-8		BASIC SKILLS	
					R	M	R	M	R	M
6. Organisms	a. identify and describe functions of cellular parts;		I, D	D, R			9		8	
	b. compare models of typical plant and animal cells;		I, D	D, R			9 10		8 9	
	c. describe organic systems from simple to complex;		I, D	R			9 10		8 9	
	d. describe simple-complex organisms on an evolutionary continuum;		I, D	D, R			9 10		8 9	
	e. identify and describe complex body systems (plant, animal and other organisms);	I	D	R	19		9 10		8 9	
	f. relate functions to structure of body systems (plant, animal and other organisms);	I	D	R	19		9 10		8 9	
	g. apply measurement skills to analysis of systems.	I	I, D	D, R	19	16 17	9 10	12	8 9	15 18

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Appendix II

Suggested Curriculum Guide Format

Concept	Objectives	Skills	Suggested activities	Suggested resources	Methods for performance appraisal
	General objectives	Subject area			
	Enabling objectives	Thinking			
		Study			

Federal law prohibits discrimination on the basis of race, color or national origin (Title VI of the Civil Rights Act of 1964); sex (Title IX of the Educational Amendments of 1972 and Title II of the Vocational Education Amendments of 1976) or handicap (Section 504 of the Rehabilitation Act of 1973) in educational programs or activities receiving federal financial assistance.

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Title VI - Peyton Williams, Jr., Associate Superintendent of State Schools and Special Services
Title IX - Myra Tolbert, Coordinator
Vocational Equity - Loydia Webber, Coordinator
Section 504 - Jane Lee, Coordinator of Special Education

Inquiries concerning the application of Title VI, Title IX, Title II or Section 504 to the policies and practices of the department may be addressed to the persons listed above at the Georgia Department of Education, 231 State Office Building, Atlanta 30334, to the Regional Office of Civil Rights, Atlanta 30323 or to the Director, Office for Civil Rights, Department of Health, Education and Welfare, Washington D.C. 20201.