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ABSTRACT

Teachers and school administrators need to give ample time to study the scope of the science curriculum. Scope refers to the breadth of objectives that should be emphasized within each science unit of study. A subject-centered approach has been used to determine scope. Thus, those involved in developing science units of study use diverse reference material to ascertain what should be taught. This paper provides teachers with suggested guidelines for teaching science and developing curricula that will be beneficial to learners presently as well as in the future. (Contains 16 references.) (CCM)

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Dr. Marlow Ediger

SCOPE AND SEQUENCE IN SCIENCE

The science curriculum needs continuous study. there are changes in science content that has been discovered by scientists and needs incorporation. For example, surrounding the planet Saturn are ringlets that just a few years ago appeared to be a solid core of rings around this planet. Facts, concepts, and generalizations in science need to be accurate and taught in an understandable manner to pupils.
The science teacher then needs to keep up with the latest information in science. Subject matter here does not stand still, but modifications and new ideas come to us from the world of science.

In addition to new subject matter being available for science teaching, modified and innovative approaches in teaching and learning are in the offing. The science teacher needs to keep abreast of methods of teaching and learning that will assist pupils to learn more optimally. Society seemingly wants higher achievement from pupils, and thus science teachers need to find the best approaches possible that help pupils learn as much as possible (Ediger, 1997, 1-17).

Inservice education to stimulate quality teaching should be in the offing. Thus, improved objectives in the science curriculum might be available to teachers in teaching/learning situations. These objectives have been carefully scrutinized to provide relevant goals for pupil attainment. Methods of instruction should highlight what is salient to stress in ongoing lessons and units of study.

The total set of objectives for pupil achievement need to be challenging, yet attainable. They need to stimulate interest in learning, but emphasize that which is salient and important, not trivia. Major concepts and generalizations should then be stressed in the ongoing curriculum. A variety of interesting procedures need to be used to guide pupil acquisition of these goals.

Learning opportunities need to possess tendencies to motivate pupils to persevere and accomplish. These activities are varied and provide for pupils of different achievement levels so that each may learn as much as possible. Learning opportunities help pupils to attain the stated science objectives. They are ordered in a manner that assist pupils to achieve, develop, and grow in science learnings (Ediger, 1995, 1-2).

A quality program of evaluation needs to be in the offing so that pupils may reveal what has been acquired and achieved. Diverse techniques of evaluation need to be used to truly determine what pupils have achieved in ongoing lessons and units in science.

Teachers, school administrators, parents, and the lay public should have a clear understanding as to what the goals of science instruction are as well as of pupil achievement gained in the science curriculum (Ediger, 1997, 55-63).

Scope in the Science Curriculum

Teachers and school administrators need to give ample time to study the scope of the science curriculum. Scope refers to the breadth of objectives that need to be emphasized within each science unit of study. A subject centered approach has been used to determine scope. Thus, those involved in developing science units of study use diverse reference materials to ascertain what should be taught. Science textbooks, university science professors, state mandated science objectives, courses of study, curriculum guides, internet science units of study presented therein, teachers, principals, national school science study groups, among others, may provide information on the scope of the science curriculum in terms of relevant subject matter. The academic disciplines, such as the earth sciences, the physical sciences, chemistry, and the biological sciences, may be analyzed to secure vital subject matter ideas. Salient content from these sources then may be stated as objectives for pupils to achieve (Ediger, 1996, 25-27). Subject matter chosen needs to be

1. significant for learners.
2. useful in dealing with problems in society, such as solving environmental dilemmas.
3. important for an educated person to know, such as current events that deal with the natural environment..
4. attainable for pupils in ongoing activities and experiences.
5. challenging to motivate pupil learning.
6. planned to provide opportunities for pupils to organize and classify content acquired.
7. flexible to encourage pupil input into each science lesson, including question raised by learners, as well as emphasizing pupil/teacher planning.
8. vital in stressing key, structural ideas in ongoing units of study.
9. evaluated using voluntary national standards and objectives.
10. appraised rather continuously to keep abreast with current trends in teaching science (See Ediger, 1994, 24-25).

By following the above named guidelines in teaching science, the teacher may offer a curriculum which will be beneficial to learners, presently as well as in the future. There is much science subject matter for pupils to learn. Thus, it is imperative to determine the scope carefully and meticulously. If the scope of science instruction pertains only to pupils acquiring relevant subject matter, narrowness in breadth of objectives for pupils to attain is indeed then in evidence. Certainly there are vital skills in science that are equally important to emphasize in ongoing science lessons and units of study.

Modes of inquiry that scientists use should be incorporated into teaching and learning situations. With skills processes inherent in acquiring subject matter in science, the scope of the curriculum should include the following for pupil achievement:

1. being a good observer. The learner then does not jump to hasty conclusions in a science experiment, but observes carefully what actually does transpire.
2. identifying questions and problems. In context, or as the need arises, the pupil identifies gaps in knowledge which require necessary information.
3. communicating ideas clearly. In a discussion setting, the learner presents ideas orally that possess meaning and clarity. Being able to communicate effectively is a must in studying scientific phenomena.
4. measuring accurately in the scientific world is important. Science tends to stress numerical data, such as in measuring force, distance, velocity, acceleration, average speed, among others, in the physical sciences.
5. classifying knowledge to bring order and meaning from a mass amount of information. Thus, vertebrates may be classified in terms of fish, amphibians, reptiles, birds, and mammals.
6. achieving reliable inferences. Not always is knowledge and data presented clear cut and precise, thus requiring pupils to develop inferences. For example, in reading United States population figures covering the years 1890 to 2000 from a table in terms of ten year intervals, a pupil needs to be able to infer what has transpired in time. Reading between the lines is necessary here.
7. thinking scientifically. Here, the pupil needs to be objective and remove all biases in thinking. Wherever the truth may lead in scientific investigations, the pupil is willing to follow evidence and analyzed reliable information.
8. using reliable reference sources. These include quality experiments and demonstrations, objective conclusions reached by qualified individuals and groups, reputable textbooks, science encyclopedias, significant internet and world wide web sources of scientific information, CD ROMS, trade books, video-tapes, films, filmstrips, illustrations, drawings, diagrams, excursions, as well as concrete, semi-concrete, and abstract materials of instruction, in general.
9. being open-minded. In science, pupils need to invite verifiable facts, concepts, and generalizations for discussion in problem solving. Testing ideas in problem solving, using experiments and

demonstrations, is salient in the science curriculum. Opposite of open-mindedness is the closed mind which does not accept evidence, even though it is trustworthy. Appreciating the methods of science in obtaining trustworthy information is vital for all children .

10. exhibiting curiosity in wanting to learn. Young children, in particular, desire to know more about the natural environment. They appear to have much interest in all facets of nature. Animal life, specifically, draws the wonder and awe of young children. As pupils progress through the different years of schooling, the science teacher has a challenge in securing the interests of and motivating pupils to attain vital science objectives (Ediger, 1999, 15-22).

Attitudinal Objectives in Science

In addition to knowledge and skills objectives, the teacher needs to stress attitudinal ends of instruction. Good attitudes help pupils in wanting to learn more science. This means that having positive attitudes toward science guides pupils to achieve knowledge and skills objectives in depth. These attitudinal, or affective objectives, goals make it possible for the learner to like learning in science in its diverse manifestations. In supervising and observing student teachers/cooperating teachers in the public schools, in talking with school administrators, and in conducting research, I have compiled the following pertaining to attitudinal goals that are relevant for pupil attainment:

1. wanting intrinsically to learn science. This inward desire to learn is perhaps the most important factor in learner achievement in ongoing lessons and units in science. There are pupils who inwardly achieve, grow, and develop in science. On their own as well as in class, their attitudes toward science and science methodology is certainly highly commendable. These are children that teachers enjoy having in science classes due to their inherent sincerity in wishing to learn more in science. Pupils can present models for others to emulate in the science curriculum. Regardless of a pupil's present status pertaining to science knowledge and skills, all need to be assisted to achieve intrinsic positive attitudes toward achieving science objectives.

2. possessing an adequate self concept. Positive feelings about the self and toward others is necessary for pupils to feel that they can achieve well in ongoing lessons and units of study in science. Helping each pupil to feel successful is one of the best ways for the teacher to guide learners to have confidence in themselves to achieve relevant objectives.

3. desiring recognition for doing well in science. By recognizing contributions of pupils, the teacher might well be providing for meeting a vital need of pupils. Meeting recognition needs might well invigorate

pupils to achieve more optimally in science. Contributions in science may be made by any pupil regardless of ability and capacity levels and this needs encouragement for all learners.

4. feelings of belonging to a committee or group is salient. Being left out from decision-making in science activities makes for negative attitudes. Seemingly, people are social beings and desire to be accepted by others. The science teacher needs to emphasize wholesome attitudes toward each other when learners are engaged in collaborative endeavors. Standards need to be established and set for group work. Evaluation of learner achievement in realizing these goals need periodic attention. Definite strivings in attaining objectives pertaining to improving human relations in group endeavors are a must. More optimal achievement in committee work should be an end result of pupils accepting each other when meeting belonging needs.

5. developing individual satisfaction in science activities and experiences. Human beings work individually and collaboratively in society. Both are important to stress as goals of instruction in science. Thus, there need to be ample opportunities for pupils to work individually in lessons and units of study. Working individually is a learning style and selected pupils achieve more optimally working by the self. Hands on experiences may involve the individual in conducting a science experiment (Ediger, and Rao, 1996, Chapter Six).

6. appreciating the contributions of science in making for a better world in health and technology. Through a study in diverse science units, learners might understand what has been accomplished by scientists to make for a more enjoyable world of work. Pupils, too, should learn to appreciate, for example, how selected diseases have been wiped out/minimized due to contributions from scientists. These deadly diseases include polio, small pox, diphtheria, tuberculosis, and mumps.

7. valuing science subject matter and skills as a means of solving problems in society as well as in school. The scientific method may be used in the identification and solutions to problem areas. Values in life provide guidance and direction to roles and responsibilities that need to be stressed in the personal dimension as well as at the work place. Values also provide assistance in becoming a good citizen and to contributions made toward furthering a better society for all.

8. achieving a desire to engage in lifelong learning. Subject matter and methods of scientific endeavors can provide interest for learning throughout one's lifespan as well as continuous development in being an educated person. Things are not learned once and for all time, but knowledge, skills, and attitudes change in time and space. Individuals need to think of learning, not as being final and fixed, but subject to modification and revision. Much knowledge and many skills arrive rather continuously and these need to evaluated and assessed in

terms of accuracy and reliability. What results should become a part of the person in an information age.

9. wanting to incorporate the latest worthwhile technology is certainly a must. Technology changes so rapidly. For example, a computer can be updated less that six months after it has been purchased! Daily updated entrees appear on the internet pertaining to science news as well as from other academic branches of knowledge. Individuals live in a world of change. Acceptance of change in technology and using what appears therein for the good of the individual and for society are vital goals.

10. showing care and concern for the self and for others is an ultimate goal that cuts across all academic disciples and citizenship duties and responsibilities in the societal arena. Interdisciplinary learnings are important for pupils in a world society that moves across borders and geographical regions (Rao and Ediger, 1996, Chapter One).

Scope and Performance Objectives in Science

Teachers and supervisors need to determine which objectives should pertain to a single unit in science instruction. Additional units in science will also need to incorporate carefully selected objectives when ascertaining scope, or what should be taught. For pupils to achieve more optimally in the science curriculum, intensive study of vital objectives by teachers and supervisors needs to be given. These ends determine what pupils might well learn in teaching and learning situations. The total number of objectives stressed within a science unit of study determine the scope for that singular unit (Talk given by Dr. Marlow Ediger, Hoosier Association of Science Teachers, Inc., Annual Convention February 19,1999, Indianapolis, Indiana).

Generally, after careful study, the chosen objectives are written in performance terms. Performance objectives are clear and direct and assist the teacher to ascertain specifically what pupils are to learn. The following are examples of how learners may reveal what has been learned and stated in terms of performance objectives for pupils to achieve in a science unit on "The Changing Surface of the Earth."

1. explain causes of soil erosion and indicate major methods used to prevent or minimize these occurrences.

2. develop a controlled science experiment to show erosion with the experimental container of soil having a grass covering as compared to the control container having no protective covering when equal amounts of water are poured on each, as well as each container having the same tilt or slope.

3. collect different types of soil, such as loam, sand, and alkali: record differences in plant growth on each type after seeding seeds of the same quality and kind.

4. report orally on happenings to soil when drouth, floods, obnoxious weeds, and harmful insects are in evidence.

5. cassette record content on a self selected library book read on conserving natural resources.

6. make a mural on earthquakes, folding and faulting, mud slides, avalanches, and glacial action.

7. collectively within a committee, complete a collage on harmful insects and weeds in the production of farm crops and livestock.

8. do a research project on the positive and negative effects in the use of pesticides and herbicides.

9. report via video-tape on the necessity of maintaining a clean source of drinking water as well as clean rivers, streams, and lakes.

10. debate land use for establishing and maintaining places for wild life refuge as compared to land use for developing shopping malls, urban sprawl housing areas, and places of business in the economic arena (See Ediger, 1995, School Science, 14-15).

The above named performance objectives, in total, provide for the scope of the science unit entitled "The Changing Surface of the Earth."

Sequence in the Science Curriculum

Sequence is an important concept to stress when arranging the order of objectives and learning opportunities for pupils to pursue within each science unit as well as among the different units taught. Quality sequence is necessary so that pupils individually may achieve as optimally as possible. If the sequence is of poor quality, learners then cannot attain as much as their abilities permit. Why? Objectives and learning opportunities that are too complex for pupil attainment and engagement might well make for feelings of failure in pupils. Whereas, objectives and learning opportunities that lack challenge for pupils may represent that which is boring. Learner enthusiasm is then dampened. Good sequence stresses that each pupil may feel challenge and the new learnings are based upon what has been taught/learned. A seamless web of achievement may then be in evidence (Ediger, 1997, 110-111).

A logical sequence may be developed. Here, the science teacher chooses and orders objectives for pupil achievement. The logic or reasoning used for sequencing the science objectives resides within the teacher. The teacher, through education, training, and experience should know which arrangement to use in ordering the objectives from the easier to those that are gradually more complex in ascending order of difficulty. He/she studies and understands pupils in the classroom in knowing what background information is possessed. The background information is then used to choose objectives whereby pupils may be successful in their achievement. If an inadequate sequence was developed, the teacher may always

1. fill in needed subject matter in which the steps in a sequence were too great, resulting in learners not attaching meaning to what is being presented.

2. review with pupils previously presented subject matter or skills so that the new learnings are understandable and meaningful.

3. move to more complex objectives if pupils indicate that the content and abilities being taught are too easy.

4. change the order of chosen objectives or learning opportunities if the wrong order had initially been chosen, as revealed from learner interaction and engagement.

5. develop new objectives if pupils reveal a lack of interest or purpose in science achievement (See Richardson and Britsch, 1997, 17.

With a logical sequence the teacher is the decision maker. Toward the other end of the continuum, a psychological sequence may be developed. Here, pupils with teacher guidance sequence their own objectives and learning opportunities emphasized in thematic or unit teaching. Learning centers stress the following:

1. the teacher works out a series of learning centers in the classroom. Perhaps, eight different centers or stations should be in the offing. Each center has concrete, semi-concrete, and abstract materials of instruction that relate directly to objectives in a science unit. Also, pupils with teacher guidance might plan these eight centers and the materials of instruction for each. In either case, there should be task cards at each center. On the task card are listed learning opportunities. Pupils may then select from all the centers which tasks to complete and which to omit so that a pupil centered sequence is truly there. Decision-making is left up to the learner. In other words, each pupil sequences his/her own order of learning opportunities to achieve viable objectives. The following is an example of tasks at one learning center in a classroom:

a. locate information from reference sources at this center to write a report on the functions of the mouth and salivary glands, the esophagus, stomach and liver, gall bladder and pancreas, as well as the large and small intestines. Use the word processor to write the final report for this long term project.

b. watch the video-tape on "Common Diseases in the Community." Make an illustrated chart and indicate preventative measures that may be taken to minimize each of the following problems: the common cold, pneumonia, tooth decay, measles, indigestion, tuberculosis, allergy symptoms, skin cancer, and aids.

c. listen to a tape recorded presentation by a local dentist and develop an illustrated movie set on dental hygiene.

d. develop a bulletin board display on "Creating a Healthy Environment." Collect and/or draw pictures for the sequential display of illustrations with written content underneath each.

e. display pictures in the classroom on "The Basic Food Groups for Healthy Living." Have pupils bring pictures to the classroom that fit under each of these basic food groups. Discuss why these foods belong under the category of "basic." (See Ediger, (1995, 371-372)

The other centers should have equally fascinating experiences that motivate pupil choice in science achievement. With learning centers, pupils individually decide the order of tasks to pursue. There are an adequate number of learning opportunities so that learners individually may omit that which is not perceived purposeful/meaningful and yet persevere fully/sequentially in each endeavor.

Additional psychological sequences in science learning might well include the use of the contract system. Here, the pupil with teacher guidance determines what he/she wishes to learn in an ongoing science unit or theme. The objectives and learning opportunities in science are clearly spelled out in the contract and, if agreed upon, signed by both the pupil and the teacher. The due date for fulfilling the contract is also written down. The motivator here is the learner himself/herself in ascertaining what to learn in a psychological sequence.

Another procedure in stressing a psychological sequence is to emphasize pupil/teacher planning of certain facets of the science unit. Here, pupil interests, questions, and concerns become paramount. For example, the pupil might be quite interested in current events pertaining to science and identify problems such as the following to pursue in the new science unit of study:

1. What causes hurricanes and tornadoes?
2. What are "lows" and "highs" when listening to a weather forecast?
3. How does a "dewpont" reading relate to fallen dew or frost on the ground?
4. Why are selected animals on the endangered species list?
5. How does a barometer work in showing air pressure? (See Ediger, 1995, 302-306)

The more pupil input there is in a science lesson or unit of study, the more likely a psychological sequence is being stressed in the curriculum. The learner then perceives order in learning when using his/her own ideas in the science curriculum.

Conclusions

Scope and sequence in the science curriculum are two vital concepts for teachers and supervisors to consider in developing the science curriculum, the teacher needs to consider the breadth of knowledge, skills, and attitudes to develop within pupils as objectives of instruction. A narrower scope would eliminate selected objectives due to time, teaching materials, and other valid reasons. A broader scope would encompass more objectives due to being more beneficial for pupils to attain additional goals, such as an integrated curriculum and having pupils engage in more depth study.

Each science unit needs to be adequate in scope to provide pupils

1. with vital knowledge, skills, and attitudes.
2. with opportunities to experience a variety of learning materials, using activities and experiences stressing the methods of science.
3. with a design that emphasizes the integrated science curriculum to incorporate reading and the language arts, social studies, mathematics, vocational experiences, art music, and physical education. Multiple Intelligences Theory suggests that teachers have pupils indicate what has been learned through the intelligence(s) possessed (See Gardner, 1993).
4. with the psychology of learning stressed from educational psychology such as pupil interest, meaning, and purpose in ongoing units of study.
5. with a caring curriculum and democracy as a way of life stressed in each ongoing lesson.

Quality sequence in science should emphasize

1. an order of objectives and learning opportunities stressed whereby each pupil might experience challenge within the new lessons being based on prior readiness experiences.
2. a logical and/or psychological order whichever benefits an individual pupil to an optimal degree.
3. learner success in ongoing lessons and units of study in science.
4. pupils perceiving connections between and among the diverse science units encountered.
5. experiments and demonstrations as the heart of the science curriculum, in a sequential placement.

Teaching science in the school setting should reflect the quality standards developed by the National Science Teachers Association (NSTA 1997). Each school system engaged in the teaching of science needs to give these national standards careful attention when improving teaching and learning situations, involving objectives, learning opportunities, and evaluation procedures.

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