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The science process in not limited to the thirteen process advocated by the American Association for the Advancement of Science (AAAS), but learning science is also supported through argumentation and science inquiry. All of these processes and skills help develop higher level, abstract, and critical thinking which is crucial in every individuals future to become successful.Scientific InquiryAccording to the National Science Teachers Association (NTSA), scientific inquiry is "the diverse ways in which scientists study the natural world and propose explanations based on the evidence derived from their work. Scientific inquiry also refers to the activities through which students develop knowledge and understanding of scientific ideas, as well as an understanding of how scientists study the natural world." From birth, children are trying to understand the world around them by interacting with their environment, asking questions, and trying to find the answers. The NTSA demands that all science teachers K-12 use scientific inquiry as an approach to teaching. Scientific inquiry is about collecting evidence to change perceptions about the world, which in turn increases students' scientific knowledge. IT involves asking questions about the world, developing investigations to answer those questions, and then supporting the evidence with reasoning. There are no fixed steps to follow and the importance of inquiry is to iterate skepticism. Students should assess their work, and their peers work, taking a skeptical eye when examining the work. Through scientific inquiry, students will perform investigations, which will teach them how to identify and ask appropriate questions and how to use the appropriate equipment and tools for analyzing the data. Students should design and conduct investigations to collect the evidence they need to answer the questions being asked. The teacher should facilitate the learning, avoiding too much confrontation so that students resolve the problem and answer the question on their own. After experimentation occurs, students should communicate and defend their results to their peers and others. They will learn how to create their own explanations. This portion of science learning incorporates literacy in the science classroom, in that students should read and write in science.Some ways to have scientific inquiry in your classroom is to plan a program where students have long-term and short-term goals, to design and manage learning environments that provide students with "the time, and resources needed for learning science through inquiry," to receive support from prior educators and administration on how to implement such procedures, and to be prepared when teaching. One way teacher can be prepared to incorporate scientific inquiry in the classroom is to practice developing appropriate questions and to practice forming those questions on one's feet. The teacher should be a scientists, questions why things work and how things work. If the teacher questions his or her surroundings, those types of thinking will rub off on the students. The students should not believe everything the teacher tells them and the teacher should encourage such behaviors and testing of truths. Another way a teacher can prepare himself or herself is to analyze the instructional materials to determine whether or not you are promoting scientific inquiry. If a teacher does not prepare a lesson that encourages questioning, questioning will not occur. Argumentation"Science is not about discovering or memorizing facts; rather it is about constructing and critiquing arguments and considering multiple explanations for phenomena." Teachers need to do more than encourage questioning, arguing, and explaining. In order to engage students, teachers need to create learning environments where students can negotiate core ideas with peers by using claims and evidence to develop their understanding about the natural world. The negotiation cycle has six phases that are each made to engage students and challenge them which will help them construct knowledge through arguments. The phases are: identifying a research questionreflecting individually through writinginvestigating in small groupspresenting group argumentspresenting revised arguments and learning crosscutting conceptsreflecting individually through writingcomparing arguments to those found in books and onlineThe negotiation cycle is a good guide to refer to when revising a lesson because it helps the teacher refer to something that will encourage students to work with one another and devise plans on how to fix a problem or how to understand the world.The framework for argument structure starts with a core idea that is one simplified statement that captures the main idea from the learning unit and that is guided into the scientific argument. From there a question is posed and a discussion or investigation occurs. Students then form a claim that poses a solution or conclusion to the question, which is supported by and leads to evidence. There should be data collected that further support the claim and reasoning done that interprets and explains the data. Students should be encouraged to question the world around them, make hypothesis of why things are the way they are, and test those hypothesis. Argumentation is about supporting your specific point of view, and collaborating with peers to better understand the question at hand. Science Process Skills Science Processes are "skills that are associated with acquiring reliable information about nature." Each process will be touched on briefly below. The first eight processes are called "basic processes" and the last five are called "integrated processes," and research shows that these process should be introduced in Kindergarten and the hypothesis testing and experimentation should continue up through high school to prepare students for college and their careers.Observation- gathering information through the senses; applied in analyticallyMeasurement- comparing some attribute of a system to a standard of reference. It can range from concrete to conditionalClassification- process of grouping objects on the basis of observable traits that are somewhat arbitrary. The more characteristics a trait is of a particular system, the closer the kinship of the shared traitsQuantification- process of using numbers to express observations rather than relying only on quantitative descriptions. This can be expressed in numerical terms so as to explore , understand, and describe nature.Inferring- inventive process in which an assumption of cause is generated to explain an observed event. This is normally influenced by culture and personal theories on nature.Predicting- projecting events based upon a body of information from whence you identify a trend and a way in which it can be testedRelationships- interaction between variables that can be influence or counter influence. This requires analytical thought that arises from cause and effect.Communication- refers to a group of skills. It can be display tables, charts, graphs, etc, and involves the ability to see and represent information beyond visual dataInterpreting data- ability to recognize patterns within date. This requires creative thinkingControlling variables- any attempt to isolate a single piece of a system so that its specific role can be interpretedOperational definitions- measurable or observable terms that should not require interpretation of meaning and is used as a research tool for controlling variables.Hypothesizing- intrinsic and creative mental process that emerges from experience and heavily depends on one's own view of the world. The explanation are seen as inventions rather than discoveries.Experimenting- systematic approach of solving a problem where each step emerges from the previous one and should be used in evaluating the hypothesis. An idea of incorporating argumentation in a classroom is that a teacher can use some sort of model relating to the Science-Cognition-Literacy (SCL) framework. This approach it combines all the previous components that a student has learned and adds a metacognitive aspect to it, or "internalization". Sometimes students have difficulty understanding the connection between knowing the data and applying it. If we were to use this approach, we would offer a reflective period for students, giving them time to ask themselves and their peers to reason how or why this hypothesis would work, along with having them connect to previous tests (in a trial and error kind of thought process). This way, the final stage of the lesson is about communicating what was learned in multiple modes (like both written and orally). That way, students comprehend the process more. We also believe literacy is not just limited to written information or books, rather it is the fusion of understanding, connecting, and application of any text. There are a lot of opportunities for students to take a step back and ask themselves and others questions about what the next step will be, is everything understood up to this point, etc. Argumentation and scientific inquiry create a sense of flexibility with student resources since while they are learning information, they are simultaneously connecting scientific principles for their future education. An example of how we can make a lesson from literacy and inquiry in science would be learning about the states of matter. Since the students are between the ages of 9-13 they would not be allowed to use the Bunsen burner until taught, so we would have to use heat to show how a solid can change to a liquid. We would change the volume, temperature, and pressure to show the changes. However, we would not simply begin by doing the experiment. First we would explain the states of matter and how they are classified with open discussion and student involvement. Then show several different drawings of molecules (many or few, moving fast or slow) and ask the students which ones they think are solid, liquid, or gas and why and to write down those answers. This is hypothesis. The lesson would spin off into discussion as students defend their reasoning until we meet a conclusion as to which set of molecules belong to which state of matter. After doing that, they would then predict what would happen to the containers I have with different conditions such as: changing the temperature, changing the volume, changing the location in the room and changing the pressure. This activity would get them: questioning their thoughts and ideas along with their classmates', interpreting scientific evidence, assessing themselves and their peers, communicating knowledge to others, and applying what they know to new situations. Reading comprehension and literacy do not simply require reading but they require all the processes listed above; that literacy is deep thinking and there are many different types of text that are not word-based but physical as well.To learn more about Science Process Skills, click here. To learn more about Scientific Inquiry, click here. SCIENCE PROCESS SKILLS Dr. Charles Barman (1992) SCIENCE, CHILDREN, & LEARNING, School of Ed -- IU - Indianapolis Dr. Barman is a co-author with dr. leyden on the Addison-Wesley science programs. The following is a developmental sequence of science process skills. The behavior attributed to the performance of each skill is categorized hierarchically with the most basic proficiency being identified first (item a) and the highest level of proficiency listed last. The chart on the last page illustrates how "most" students would develop each skill if they were provided with the appropriate learning experiences to use these skills at each grade level (N-12). BASIC SKILLS 1. Skill--Observation Making observations is fundamental to all learning. Observations are made by using one or more of the five senses. When observations are made to accumulate data from which inferences will be drawn, the precision of the observations is critical. Precision is often improved by making quantitative observations. Skill Sequence -- The student will be able to: a. Distinguish differences in physical properties of objects by direct observation. b. Manipulate or change an object in order to expose its properties. c. Use instruments to aid the senses in making observations. d. Make observations (not inferences). e. Repeat observations as a means of improving reliability. f. Use measurement as a means of refining observations. g. Order events chronologically. h. Identify changes in properties and measure rates of change. i. Differentiate constants from other variables. j. Identify correlational changes in variables. 2. Skill--Classification Classification is the grouping or ordering of phenomena according to an established scheme. Objects and events may be classified on the basis of observations. Classificational keys are used to place items within a scheme as well as to retrieve information from a scheme. Skill Sequence -- The student will be able to: a. Perceive similarities and differences in a set of objects. b. Separate a set of objects into two groups according to those that have or do not have a single characteristic. c. Group a set of objects on the basis of a gross characteristic, such as color or shape, where many identifiable variations are possible. d. Develop arbitrary one-stage classificational schemes where all included objects of phenomena may be put into mutually exclusive categories. e. Use quantitative measurements as criteria for grouping. f. Develop classificational schemes of two or more stages of subsets having mutually exclusive categories. g. Use an accepted classification system or key to identify objects or phenomena. 3. Skill--Inference An inference is an idea based on an observation or set of observations. Making an inference requires evaluation and judgment based on past experiences. Inferences lead to prediction. Skill Sequence -- The student will be able to: a. Demonstrate that inference is based upon observation. b. Separate pertinent observations upon which given inferences are based from those which are extraneous. c. Develop an inference from a set of related observations. d. Develop a series of inferences from a set of related observations e. State cause-and-effect relationships from observation of related events. f. Identify limitations of inferences. g. Develop plans to test the validity of inferences. h. Use inferences to suggest further observations. i. Extend inferences to formulate models. 4. Skill--Prediction Prediction is the formulation of an expected result based on past experience. The reliability of prediction depends upon the accuracy of past observations and upon the nature of the event being predicted. Prediction is based upon inference. An experiment can verify or contradict a prediction. Skill Sequence: -- The student will be able to: a. Distinguish between guessing and predicting. b. Use repeated observations of an event to predict the next occurrence of that event. c. Use a series of related observations to predict an unobserved event. d. Use quantitative measurement as a means of improving the accuracy of predictions. e. Use interpolation and extrapolation as a means for making predictions. f. Establish criteria for stating confidence in predictions. 5. Skill--Measuring Measuring properties of objects and events can be accomplished by direct comparison or by indirect comparison with arbitrary units which, for purposes of communication, may be standardized. Skill Sequence -- The student will be able to: a. Order objects by inspection in terms of selected common properties such as size, shape and weight. b. Order objects in terms of properties by using measuring devices without regard for quantitative units. c. Compare quantities such as length, area, volume and weight to arbitrary units. Compare time to units developed from periodic motions. d. Use standard units for measurements. e. Select one system of units for all related measurements. f. Identify measurable physical quantities which can be used in precise description of phenomena. g. Convert from one system of units to another. h. Use and devise indirect means to measure quantities. i. Use methods of estimation to measure quantities. 6. Skill--Communication In order to communicate observations, accurate records must be kept which can be submitted for checking and re-checking by others. Accumulated records and their analysis may be represented in many ways. Graphic representations are often used since they are clear, concise and meaningful. Complete and understandable experimental reports are essential to scientific communication. Skill Sequence -- The student will be able to: a. Describe observations verbally. b. Describe conditions under which observations were made clear. c. Record observations in a systematic way. d. State questions and hypotheses concisely. e. Construct tables and graphs to communicate data. f. Plan for communication of procedures and results as an essential part of an experiment. g. Report experimental procedures in a form so other persons can replicate the experiment. h. Use mathematical analysis to describe interpretations of data to others. Use tables and graphs to convey possible interpretations of data. INTEGRATED SKILLS 7. Skill--Interpreting Data Interpreting data requires the application of other basic process skills-- in particular, the processes of inferring, predicting, classifying, and communicating. It is through this complex process that the usefulness of data is determined in answering the question being investigated. Interpretations are always subject to revision in the light of new or more refined data. Skill Sequence -- The student will be able to: a. Select data pertinent to the question asked. b. Process raw data to explain trends or relationships. c. Describe information as it is displayed on tables or graphs. d. Make and explain inferences from tables or graphs. e. Set criteria for assessing the validity, precision, and usefulness of data. f. Compare sets of related data to test the credibility of inferences and generalizations. g. Select the most acceptable interpretation from multiple interpretations of the same set of data. h. State criteria for restricting inferences and generalizations to those inferences and generalizations supported by data. 8. Skill--Making Operational Definition Operational definitions are made in order to simplify communication concerning phenomena being investigated. In making such definitions it is necessary to give the minimum amount of information needed to differentiate that which is being defined from other similar phenomena. Operational definitions may be based upon the observable characteristics of the phenomena and upon the operations to be performed. Operational definitions are precise and, in some cases, based upon mathematical relationships. Skill Sequence -- The student will be able to: a. Distinguish between an operational definition and a general description. b. Select characteristics of phenomena suited to use in an operational definition. c. State minimal observable characteristics required for an operational definition. d. Evaluate and modify specific operational definitions. e. Describe the limitations of operational definitions. f. Use mathematical relationships in making operational definitions. g. Formulate operational definitions of experimental parameters such as system boundaries, data gathering procedures and interactions of variables. 9. Skill--Forming Questions and Hypotheses Questions are formed on the basis of observations made and usually precede an attempt to evaluate a situation or event. Questions, when precisely stated, are problems to be solved through application of the other processes of science. The formulation of hypotheses depends directly upon questions, inferences and prediction. The process consists of devising a statement which can be tested by experimentation. When more than one hypothesis is suggested by a set of observations, each must be stated separately. 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An experimental test of a hypothesis is designed to indicate whether the hypothesis is to be accepted, modified or rejected. In designing an experiment, limitations of method and apparatus must be considered. Skill Sequence -- The student will be able to: a. Manipulate materials to make pertinent observations. b. Identify relevant variables in an experimental situation. c. Distinguish useful from extraneous data. d. Maintain an accurate record of experimental procedures and results. e. Control those variables not part of the hypothesis being tested. f. Identify sources of experimental error. g. Describe the limitations of experimental apparatus. h. Describe the limitations of the experimental design. 11. Skill--Formulating Models Models, whether physical or mental, are devised on the basis of acceptable hypotheses or hypotheses that have yet to be tested. Models are used to describe and explain the interrelationships of ideas. 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GRADE LEVEL CHART The "N" and "K" grade levels indicate the desirability of working with specific skills prior to beginning an emphasis on concept development. The arrows indicate the range over which the skills should be developed. The letters on the arrows indicate specific behaviors as described in each skill sequence.

SCIENCE PROCESS SKILLS Dr. Charles Barman (1992) SCIENCE, CHILDREN, & LEARNING, School of Ed -- IU - Indianapolis Dr. Barman is a co-author with dr. leyden on the Addison-Wesley science programs. The following is a developmental sequence of science process skills. The behavior attributed to the performance of each skill is categorized hierarchically with the most basic proficiency being identified first (item a) and the highest level of proficiency listed last. The chart on the last page illustrates how "most" students would develop each skill if they were provided with the appropriate learning experiences to use these skills at each grade level (N-12). BASIC SKILLS 1. Skill--Observation Making observations is fundamental to all learning. Observations are made by using one or more of the five senses. When observations are made to accumulate data from which inferences will be drawn, the precision of the observations is critical. 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