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UNIT ONE(1)

NATURE OF SCIENCE

OUTLINE

- Meaning f Science
- Science as a Process and Science as a Product
- Characteristics of Scientific Knowledge
- Scientific Attitudes and Values
- Science, Technology and Society
- Science and Traditional Beliefs System

OVERVIEW

- This unit will take you through the nature of science.
- You will learn about the meaning and categories of science, uses of science in different fields, characteristics of scientific knowledge, and scientific attitudes and values.
- The unit will end with discussion on science, technology and society as well as relationship between science and traditional beliefs system.

Definitions of Science

- Science comes from the Latin word **Scientia** which means **knowledge**.
- Science is a discipline that involves systematic observations and experiments of natural phenomena.
- Science may be defined as:
  - *A method of exploring the environment by observing things and solving problems.*
  - *The gathering and recording of information to find answers to questions and challenges of human race.*
  - *A method of obtaining knowledge through observation and experimentation.*
  - *A process of generating knowledge.*

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- *A way of learning that involves firsthand experiences, inquiry, problem solving, communication of findings.*
- *That body of knowledge which can be communicated to others, and which can be verified by anyone willing to make the efforts to do so.*

- From the various meaning of science, we can now say that: *science is a way of learning which involves firsthand experiences, inquiry, problem solving, interpretation and communication of findings.*
- Science is a process of generating knowledge and a search for explanation.

Categories of Science

- **Pure science**: Pure Science deals with the attempt to understand nature
- **Applied Science:** Applied Science deals with the use of the knowledge acquired in pure science.

Branches of Pure Science

- **Biology** is the study of living organism (plant and animal) and their interactions with each other and the environment. Example: Zoology, microbiology, botany, physiology. Career opportunities are: Medical doctor, Botanist, Teacher, Oceanographer, Microbiologist, Biologist.
- **Chemistry** is the study of matter and its reactions. Example: Pharmacology, forensics, toxicology. Careers in studying chemistry include Pharmacist, Oceanographer, Teacher, Forensic scientist, Chemist.
- **Physics** is the study of energy and its influence on matter. Example: Engineering. Career opportunities available include Astronomer, Oceanographer, Teacher, Meteorologist, Engineer, Physicist

Fields of Applied Science

- Some fields of applied science are meteorology, engineering, medicine, pharmacy, geography, agriculture, forestry, horticulture, environmental health, sociology, geology, psychology and astronomy.

Importance of Science in Everyday Life

- Science is essential in our daily life.
- We wake up and use paste and brush which both are given by science.
- We use science in everyday life activities such as cooking, eating and clothing.
- Baking involves knowledge of science and baking machines such as oven and microwaves are endowments of science.
- Can you imagine your life without electricity? If no, then you must know that electricity is also given by science.

Uses of Science in Different Fields

- **Agriculture**: In the field of agriculture, science has made its mark by contributing so much. In present days machines are available even for sowing the seeds on the field. Tractor, thresher, irrigation systems (both drip and sprinkler), etc. all are given by science.
- **Medicine**: The medical field is based entirely on science. All drugs are given by medical chemistry. Discovery of vaccines and antibiotics in the field of medicine helps in controlling infectious diseases and reduces death rate.
- **Transportation**: All the vehicles are invention of science. You can reach from Accra to Tamale in few hours. We can transport goods early and faster by the use of machines given by science

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- **Communication**: Science has made the world very small. You can talk to everyone anywhere in fraction of seconds. Telephones, mobile phones etc. all are the inventions of science. Invention of satellites has made communication more effective and faster.
- **Construction**: Science is the base of all buildings constructed by us. Constructions of building is completely based on technology given by science. Machines used in the construction work such as motor graders, bulldozers, back-hole loaders are given by science.
- **Photography**: Science has many machines for photography. Nowadays, it is very easy to click and snap a picture. Camera has been inserted even in our mobile phones.

Self-Assessment Questions

- What is science?
- How will you explain science as a body of knowledge?
- Discuss the importance of science in everyday life.

Science as a Process

- The processes of science are the procedures used by scientists to arrive at solutions to their problems.
- These are the practices employed in science to uncover knowledge and interpret the meaning of those discoveries.
- It involves observation, measuring, calculating, manipulating, predicting, hypothesizing, classifying, raising questions, inferring, communicating, etc.

Science as a Product

- The procedure you use to arrive at a conclusion is referred to as Process of Science.
- The scientist ends up an investigation or research by making discoveries of facts and concepts, formulating generalizations, theories and laws.
- These are known as ‘Products of Science’.
- Examples are facts drawn from experiments, theories such as Atomic Theory and Mendel’s Theory, law such as law of gravity, law of conservation of water, law of floatation, and principles such as Archimedes’ principles.

Differences between the Scientific Process and the Products of Science

- Science as a process can be defined as the organized way of gathering knowledge on a subject, through various observations and experiments whereas the practical usage of the laws of science for different purposes can be referred to as science as a product.
- Science as a process is a way of exploring new knowledge, whereas science as a product is putting scientific knowledge into practice.
- Scientific process is very useful to gain knowledge about a natural phenomenon, and their reasons. On the contrary, scientific product can be useful or harmful, i.e. technology is both a boon and bane, such that if it is used in the right way, it can help humans in solving a number of problems, however, if it is put to wrong uses, it can cause destruction of the whole world.

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- Science as a process remains unchangeable; only additions are made to further knowledge. Conversely, science as a product changes at a rapid pace, in the sense that, improvement in previous technology is made constantly.
- Science as a process stresses on discovery, like facts and laws of nature. Unlike scientific products which focuses on the inventions, such as the development of latest technique, to ease the work of humans.
- Science as a process involves the study of structure and behaviour of natural and physical world, to create premises. In contrast, science as a product deals with putting those premises into practice.

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- Science as a process is concerned with analysis, deduction and theory development. On the other hand, science as product is based on analysis and synthesis of design.
- Science as a process is used to make predictions whereas science as a product simplifies the work and fulfill the needs of people.

Self-Assessment Questions

- What is the process of Science?
- State the products of science.
- Identify the difference between the scientific process and product of science.

Characteristics of Scientific Knowledge

- **Objectivity**: Objectivity simply means the ability to see and accept facts as they are, not as one might wish them to be. To be objective, one has to guard against his own biases, beliefs, wishes, values and preferences. 2. Verifiability
- Science rests upon **sense data**, i.e., data gathered through our senses – eye, ear, nose, tongue and touch. Scientific knowledge is based on verifiable evidence (concrete factual observations) so that other observers can observe, weigh or measure the same phenomena and check out observation for accuracy.

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- **Ethical Neutrality**: It only seeks knowledge. How this knowledge is to be used, is determined by societal values. Knowledge can be put to differing uses. Knowledge about atomic energy can be used to cure diseases or to wage atomic warfare. Ethical neutrality does not mean that the scientist has no values. Its only means that scientist must not allow his values to distort the design and conduct of his research.
- **Systematic Exploration**: A scientific research adopts a certain sequential procedure, an organized plan or design of research for collecting and analysis of facts about the problem under study.
- **Reliability**: Scientific knowledge must occur under the prescribed circumstances not once but repeatedly. It is reproducible under the circumstances stated anywhere and anytime. Conclusions based on casual recollections are not very reliable.

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- **Precision**:. It is not vague like some literary writing. Precision requires giving exact number or measurement. Instead of saying "most of the people are against same sex marriages," a scientific researcher says, "Ninety per cent people are against same sex marriages".
- **Accuracy**: Accuracy simply means truth or correctness of a statement or describing things in exact words as they are without jumping to unwarranted conclusions.
- **Predictability**: Scientists do not merely describe the phenomena being studied, but also attempt to explain and predict as well. It is typical of social sciences that they have a far lower predictability compared to natural sciences.

Self-Assessment Question

- Explain each of the following characteristics of scientific knowledge:
  - Objectivity
  - Verifiability
  - Ethical Neutrality
  - Reliability
  - Predictability

Scientific Attitudes and Values

- In our everyday life, we depend upon our senses to know about what is going on around us i.e., by what we see, hear, feel, taste, or smell, but in our work in science, we often have to deal with things that we cannot sense.
- Our attitude of science must be objectivity.
- When we are making investigations in science, we must make sure that our feelings, senses or belief systems do not influence the observations we record i.e., during science activities, we must be open minded and interpret data objectively.
- We have to make accurate measurements, record and analyse facts honestly and confidently.

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No.	Scientific Attitudes and Values	Explanation
1.	Open mindedness	Scientists must accept the fact that science is a human idea and that our future citizens must learn from experience. Scientists must therefore be able to revise their opinions and conclusions in light of new evidence.
2.	Curiosity	The inclination or feeling toward seeking information about how things work in a variety of fields.
3.	Perseverance	The ability to continuously pursue an investigation until results are achieved.
4.	Respect for evidence	Willingness to collect and use data in one's investigation and also have respect for data collected by others.

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5.	**Reflection**	**The habit of critically reviewing ways in which an investigation has been carried out to see possible faults and other ways in which the investigation could be improved.**
6.	Honesty	Intellectual honesty is concerned with the conscious act of truthfully reporting observation. Report is seen but not what is taught to be seen.
7.	Critical mindedness	Scientists look for evidence and argument that support another person's ideas
8.	Thoroughness	Scientists are not expected to draw hasty conclusions, judgement is only pronounced after enough data and evidence have been covered to support conclusion drawn.

Some Values in Science

- **Longing to know and understand**: A conviction that knowledge is desirable and that inquiry directed towards its generation is a worthy investment of time and other resources.
- **Questioning of all things**: A belief that all things including authoritarian statements and self-evidence truths, are open to questions
- **Request for logic**: An esteem for those chains of inference that lead from raw data to conclusion according to some logical scheme and an insistence that conclusions or actions not based on such chains be subject to doubts.
- **Consideration of premise**: a prizing of frequent review of the basic external and internal assumptions from which a line of inquiry has arisen, especially when they are used as basis for determining further action.

Self-Assessment Question

- Explain the following scientific attitudes:
  - Open-mindedness
  - Curiosity
  - Critical mindedness
  - Reflection

Science, Technology and Society

- Science, Technology and Society (STS) is an interdisciplinary field that studies the conditions under which the production, distribution and utilization of scientific knowledge and technological systems occur; the consequences of these activities upon different groups of people.

Science in Transition

- In the past, our scientific methods and institutions have tended to emphasize the study of individual natural processes rather than systems, analysis more than synthesis, and understanding nature more than predicting its behaviour.
- And in many instances, science has focused on short-term, small scale problems, often in monodisciplinary mode, rather than on long-term, large-scale, or integrated problems.
- While these approaches and perspectives have built up a considerable base of knowledge and led to a vast portfolio of useful technologies, especially in the 20th century, many of the problems now facing humankind can be solved only if we approach science more holistically.

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- The impact of technological interventions on individual people, communities and the environment must also be carefully considered.
- To do this, science needs to become more multidisciplinary and its practitioners should continue to promote cooperation and integration between the social and natural sciences.
- A holistic approach also demands that science draw on the contributions of the humanities (such as history and philosophy), local knowledge systems, aboriginal wisdom, and the wide variety of cultural values.

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- The influence of science on people’s lives is growing.
- While recent benefits to humanity are unparalleled in the history of the human species, in some instances the impact has been harmful or the long-term effects give causes for serious concerns.
- The power of science to bring about change places a duty on scientists to proceed with great caution both in what they do and what they say.
- Scientists should reflect on the social consequences of the technological applications or dissemination of partial information of their work and explain to the public and policy makers alike the degree of scientific uncertainty or incompleteness in their findings.

Integrating Issues - Science and Society

- Advances in science and its resulting technologies, such as global communication, satellite images of Earth, together with the popular fascination with dinosaurs etc., have irrevocably expanded the space and time scales with which people at many levels of society now view their world.
- Science is largely responsible for a growing public awareness that people share the planet with all other living creatures, that the environment which supports all life is subject to change, and that human activities are presently changing this environment and threaten to change it seriously.
- In the past two centuries, science has been used mainly as a tool for economic expansion and military power for the wealthier segments of the human race.

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- It is now clear that the current consumption of natural resources and increasing stresses on the regional and local environment cannot continue indefinitely without breakdown of the natural support systems that make present civilizations possible.
- Science, which helped to bring about this situation, now has an over-riding responsibility to help societies make a transition from an obsession with growth to achievement of a dynamically stable and sustainable ecological and economic system.
- In this transition, an alliance between modern technical science and the holistic wisdom from indigenous societies and philosophers from all cultures can be very important.

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- In the coming century, the rate of change of natural and human conditions and issues can be expected to continue to accelerate.
- Scientists have an increasing obligation to become involved with policy-makers and the public in finding and implementing solutions or means of adaptation to issues that are both local and world-wide, such as reconciling the present competitive profit motive with the common good; providing for contributions from and benefits to marginalized elements of society and minority cultures; justifying current expenditures to prevent costs or damages to future generations; rewarding collective rather than individual efforts.
- The role of science in society and governance has never been more important.

Relationship between Science and Technology

- Technology is the application of scientific knowledge for human use, i.e., technology can be taken the direct product of science.
- The relationship between science and technology may be seen in the table.

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Science	Technology
A knowledge-generating process	A process by which scientific knowledge and discovering are applied and used
A way of learning which involves first hand experiences, inquiry, problem solving, interpretation and communication of ideas	A disciplined process using scientific material and human resources to achieve human purpose
The product of science cannot be seen or touched (intangible)	The product of technology such as electric fan, refrigerator etc. can be seen and touched (tangible)
The product of science can be demonstrated and understood	The product of technology be bought and use without understanding.

Self-Assessment Questions

- Explain how science, technology and society are interrelated.
- Differentiate between science and technology.

Relationship between Science and Traditional Beliefs System

- Much of the troubles in the world arise because many people do not think scientifically.
- The believe anything that they read without inquiring into these statements and testing their truth.
- Most of the traditional beliefs in Ghana are based on reward-punishment concept.
- This reward-punishment concept is used to conceal the real scientific basis of what is being said.

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- Traditional beliefs are held for the various reasons as:
  - To maintain personal hygiene and to check the spread of diseases.
  - To prevent cruelty to other people and to animals
  - To give personal safety of individual and society.
  - To instill good social habits.

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- We may put traditional beliefs in Ghana into two groups which may be:
- Those that can be explained in terms of science. Example, one mother would die if sings while bathing.
- **Scientific explanation**: To produce sound, air must be expelled from the lungs, and to get enough air for this activity, the singer must inhale large amount of air. That is, when one sings whilst bathing there is possibility of inhaling water and soap into the lungs. The presence of these items in the lungs is harmful and might cause death. The child is therefore deterred from singing while bathing in order not to cause the death of their mother whom they love so much. Secondly caustic soda which is used in preparing soap is very strong (highly corrosive) and this will cause serious burns when it gets to the lungs. Thus, the child is barred from singing

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- Another example: One should not talk whilst eating else the offender will die
- **Scientific explanation**: In talking, sound is produced by expelling air from the lungs and inhaling large volumes of air. So, when one talks whilst eating there is the possibility of food getting into the lungs. The presence of food in the lungs is harmful and this might cause death. The child is barred from talking in order not to die.
- Those that cannot be explained in terms of science are superstitions. Example: One when one dies, he/she goes to the underworld.

Effects of Traditional Belief on Science Teaching

- Makes the teaching and learning of science very difficult because the pupils/students are reluctant to assimilate what they see as inconsistent with their local life.
- The local beliefs could be a good source for the application of science knowledge.
- Sensitizes science teachers to relate scientific knowledge to home knowledge.
- Makes students appreciate the wisdom of local folks.
- Arouses curiosity in the student and this leads to research.
- It promotes superstition which is inconsistent leads to research.

Self-Assessment Questions

- What is a traditional belief?
- Discuss any two (2) effects of traditional belief on science teaching.
- State three reasons why beliefs are held.

THANK YOU

UNIT 2

SCIENCE PROCESS SKILLS

OUTLINE

- What are Science Process Skills?
- Basic Process Skills
- Integrated Process Skills
- Developing Basic Process Skills in Students
- Developing Integrated Process Skills in Students
- Assessment of Science Process Skills

OVERVIEW

- The purpose of science education is to help individuals to become scientifically literate.
- Scientific literacy enables individuals to understand the nature of science and the natural world. Science is about asking questions and finding answers to them. In finding answers to these questions scientists use certain processes.
- The processes of doing science are the process skills that scientists use to understand the world.
- Understanding the world requires the use of process skills such as observing, communicating, predicting, inferring, hypothesizing and experimenting.
- These process skills are needed to gather information about the individual's environment.
- This unit is on science process skills. We hope that you will enjoy the unit.

What are Science Process Skills?

- Science process skills are a set of abilities appropriate to many science disciplines that reflect the behaviour of scientists.
- They are skills that are used by individual in their daily life activities to gather information about their surroundings.
- They are grouped into two types. These are basic and integrated process skills.
- Basic process skills are simpler skills used in everyday life transactions.
- The most commonly used basic process skills are observing, inferring, measuring, communicating, classifying and predicting.

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- Basic process skills provide the foundation for learning integrated process skills.
- Integrated process skills are more complex than the basic process skills.
- They are a blend of two or more basic process skills.
- They are the combination of the various skills that are required to carry on complex activities or to solve problems encountered in everyday life activities.
- The most commonly used integrated process skills are controlling variables, defining operationally, formulating hypothesis, interpreting data, experimenting, formulating models and raising question.

Importance of Science Process Skills

- Science process skills develop core competencies such as scientific thinking, critical thinking, creative thinking, problem solving, and personal and social development in individuals.
- They promote collaborative skills, effective communication skills, scientific literacy and digital literacy.
- Science process skills also allow individuals to become global citizens and enable them to acquire first hand hands-on and minds-on experiences.
- Acquisition of science process skills helps individuals in their daily life transactions since these skills form an integral part of life and are used in every area of life.

Self-Assessment Questions

- Describe science process skills.
- Differentiate between basic and integrated science process skills.
- Describe the importance of science process skills.

BASIC PROCESS SKILLS

- **Observing**: Science begins with observation.
- Observation is the skill of using the five senses to gather information or evidence about an object or event.
- It is the most basic science process skill.
- Observation helps us to know about the natural world.
- Good observation of objects and events are essential in everyday life activities and needed in developing other process skills.

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- There are two types of observation.
- These are qualitative and quantitative observations.
- Qualitative observations are observations that involve the use of only the senses.
- For example, the learner can use the eyes to make an observation of the colour of a pen and describe the colour as red.
- Quantitative observations involve the use of a number to describe the observation made.
- They give more precise information. For example, there are three balls in the bucket.

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- **Communicating**: When students make observations, they must describe their observations.
- Students have to communicate with their peers and teachers about their observations.
- Communicating is using words or graphic symbols to describe an action, object or event.
- For example, describing the change in height of a plant over time in writing or through a graph.
- In other words it is being able to present information so that it can be understood by others, and also being able to understand information from others presented in various forms using graphs, charts, written instruction, diagrams, pictorial and oral representation. Communication must be very clear and well understood.

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- **Measuring:** Measuring is making a quantitative observation.
- This is because a measurement statement contains a number and a unit.
- Measuring is using measuring instruments to describe the dimensions of an object or event.
- It is the accurate use of measuring instruments and equipment for measuring, reading and making observations.
- For example, one can use metre stick to measure the length of a table in centimetres.
- Measuring is important in collecting, comparing, and interpreting data.
- It helps us classify and communicate with others.

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- **Classifying**: After making observations it is important to notice similarities, differences, and group objects according to a purpose.
- It is important to create order to help comprehend the number of objects, events, and living things in the world.
- Grouping objects or events is a way of imposing order based on similarities, differences, and interrelationships.
- This is an important step towards a better understanding of the different objects and events in the world.

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- **Inferring**: Observations are direct evidence gathered about an object or event.
- The explanations that follow from the observations are the inferences.
- Therefore, an inference is based on an observation.
- It is a link between what is observed and what is already known.
- Inferring is when one deduces or concludes (something) from reasoning rather than from explicit statements

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- **Predicting** is the skill of assessing the likelihood of an outcome based on prior knowledge of how things usually turn out.
- It is using ideas or evidence to determine the outcomes of future events.
- When we make a prediction it means that we are forecasting future observations.
- The ability to make predictions about future events allows us to successfully interact with the environment around us.
- Prediction is based on both good observation and inferences made about observed events.
- Like inferences, predictions are based on both what we observe and also our past experiences.

Self-Assessment Question

- Explain at least three (3) of the six most commonly used basic science process skills

INTEGRATED PROCESS SKILLS

- **Controlling variables:** The characteristic or phenomenon that can be measured or classified is called a variable.
- Anything that can vary can be considered a variable.
- It is an entity that can take on different values in different persons, places, or things. Examples of variables are height, weight, heart rate and age.
- Age can take different values for different persons or for the same person at different times
- In science we study the effect of one variable over the other.
- For example, if you want to study the effect of the use of teaching support materials on the learning outcomes of your students, there are two main variables involved.
- These are teaching support materials and learning outcomes.

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- There may be other factors that may affect learning outcomes such as classroom management, teacher's content knowledge and students' readiness but you are only interested on the effect of just one variable, which is, teaching support materials on the learning outcomes of your students.
- Therefore, the other variables will have to be controlled or kept constant.
- So controlling variables is being able to identify variables that can affect an experimental outcome, and keeping them constant while manipulating only the variable of interest.
- Another example is realizing through past experiences that amount of light and water need to be controlled when testing to see how the addition of organic matter affects the growth of beans.

Defining operationally

- This is the ability to state how to measure a variable in an experiment.
- For example, stating that bean growth will be measured in centimeters per week.
- Whatever information individuals acquire through experiments such as observations or experiences are used to describe in meaningful statement a phenomenon, object or event.

Formulating hypothesis

- A hypothesis is a specific statement of prediction.
- It describes in concrete terms what you expect to happen in future.
- It is formulated to explain observations and to make quantitative predictions of new observations.
- Formulating hypothesis is stating the expected outcome of an experiment or giving possible explanations of an event or phenomenon.
- It is also suggesting reasons for events or phenomena, which can be tested scientifically. It involves applying concepts and ideas from previous experience.
- For example, the greater the amount of organic matter added to the soil, the greater the bean growth.

Interpreting data

- Interpreting data is giving meaning to information gathered or explaining the meaning of information or actions.
- It is considering evidence, evaluating the evidence and drawing conclusions from it.
- For example, recording data from an experiment on bean growth in a data table and giving explanation which relates trends in the data to variables.

Planning and conducting experiments

- Planning and conducting experiments or investigations is devising inquiries.
- Planning an experiment is devising how to conduct the experiment.
- Experimenting is the process that involves interaction with materials to find out things for yourself or managing the factors that may influence a situation or event so that the effect of a given factor may be learned.
- Experimenting is being able to conduct an experiment, including asking an appropriate question, stating a hypothesis, identifying and controlling variables, operationally defining those variables, designing an experiment, conducting the experiment, and interpreting the results of the experiment.
- Designing and conducting an experiment requires the use of many skills.

Formulating models

- The information received or the knowledge gained through the study of data helps the investigator to test the hypothesis or form conclusions.
- You can study the table and conclude that the amount of solute dissolved in one litre of solution increases with rise in temperature or the volume of a gas decreases with rise in pressure.
- Therefore, formulating models is creating a mental or physical model of a process or event.
- An example is the model of how the processes of evaporation and condensation interrelate in the water cycle.

Raising questions

- Raising questions in students is developing their ability to use effective questions to elicit information about the world.
- It is recognizing and defining investigable questions to build their capacity as young scientists.
- Students should be able to examine and discover ideas, principles and facts by asking questions.
- Raising questions among students will help to determine the level of their understanding of phenomena or events, clear their misunderstanding of ideas or intellectual ability of students on everyday occurrences, and motivate them to learn more to satisfy their curiosity.

Self-Assessment Question

- Explain at least three (3) of the six most commonly used integrated science process skills.

Developing Basic Process Skills in Students

- Students should actively take part in in classroom activities that promote the development of the basic process skills.
- Classroom activities such as discussion, group work and presentations will promote the communicative skills of students.
- Furthermore, taking part in group work that involves measuring, classifying, inferring and predicting will also help to develop these abilities in students.
- In developing observing skills among students for example, the students must make good observations.

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- Students should be able to give detailed descriptions of their observations.
- Students should make both qualitative and quantitative observations and give elaborate descriptions of their observations.
- When students are able to give detailed descriptions of their observations, they tend to understand lesson content better.
- Table 1 shows some generic classroom activities that will nurture the development of science process skills among students.

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Activity	Process
• letting learners observe the demonstration of the process of evaporation • letting the learner close the eyes and make observations using the sense of touch	Observing
• letting learners observe specimens and describe their features	Observing and communicating
• Let students engage in the measurement of physical quantities	Measuring
• Put students in groups and let them classify objects	Classifying

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Activity	Process
• asking learners to describe the colour of oranges • letting students think, pair and share ideas after an activity • After an experimental activity, let students in groups write their reports, discuss them, and present them in class • Create opportunities for learners to give the summary of the lesson	Communicating
Create opportunities for students to engage in making inferences	Inferring

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Activity	Process
• Encourage students to predict the outcomes of events and investigations • Create opportunities for learners to make a prediction in relation to a problem	Predicting

Self-Assessment Question

- Describe two activities that will promote the development of the following process skills:
  - Observing
  - Communicating
  - Predicting

Developing Integrated Process Skills in Students

- In everyday life activities students use integrated process skills such as hypothesising, interpreting and experimenting.
- This means that students should develop these abilities to be able to make life easier for them.
- Students should participate actively in experiments because designing and conducting an experiment requires the use of many skills such as formulating hypothesis, controlling variables, defining operationally, interpreting data and formulating models.

ACTIVITY GUIDE

Activity	Process Skill
• Create opportunities for students to engage in investigations where certain variables are controlled. For example, investigating the effect of light on the growth of plants whiles controlling other variables that influence plant growth like air and water.	Controlling variables
• Create opportunities for students to state how to measure a variable in an experiment	Defining operationally

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• **Let students present their ideas for their peers to reflect, critically analyze and evaluate.** • **Create opportunity for students to interpret the findings of investigations and their observations.**	**Interpreting data**
• Create opportunities for students to be involved in devising how to conduct investigations	Planning experiments

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• **Create opportunities for students to engage in scientific investigations**	**Conducting experiments**
• Create opportunities for students to perform many investigations to test hypotheses and form conclusions so that they will cultivate the skill of creating mental or physical models of processes and events.	Formulating models
• Ask thought provoking students to elicit questions from students • Create opportunities for students to also ask questions	Raising questions

Self-Assessment Question

- Describe one activity that will promote the development of the following process skills
  - experimenting skills
  - controlling variables
  - hypothsesizing

Assessment of Process Skills

- The use of process skills helps students to use scientific evidence to solve problems and make decisions.
- Therefore, it is imperative to ensure that students develop these skills and use them in everyday life transactions whiles in school and after completing.
- To find out whether students have develop these skills means that the skills should be assessed to ascertain the level of development in students.
- Assessment of process skills is necessary to find out whether they have been raised in students.

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- Assessment is a way of gathering information about student performance or developing science process skills among students in this context.
- It is the process of gathering and interpreting evidence to make judgement about the development of these skills.
- Classroom teachers usually collect evidence about students' learning, interpret this evidence to know the current level of students to determine where to take them, and guide students to the required level of achievement (Exploratorium, 2006).
- Information gathered from assessment is crucial to make instructional decision to help students take next steps in their learning.
- Formative assessment strategies are usually used by teachers to help students develop their process skills.

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- Assessment of process skills can be done using a variety of assessment strategies but the most direct way to assess these skills is through observation.
- When teachers observe students they are able to find out whether the studentsare really using the process skills they have acquired.
- Do students actually make a prediction, observe, communicate, measure, plan and execute investigations? How well do they do these?
- Teachers need to observe learning and follow up with questions to find the reasons behind the learning.

Cont’d

- This means that direct observation followed by interrogation is key to finding out the level of development of process skills in students.
- For example, a teacher can let students make a prediction relating to a problem and later interrogate the reasons behind the prediction to determine the level of development of prediction skills in students.
- In addition, students’ writing about science can indicate their use of science process skills as well.
- Teachers can also use student writing as evidence of science process skill development.

Indicators for Assessing Process Skill Development

- Exploratorium (2006) proposes some questions that examine developmental levels of process-skill development.
- The questions serve as a guide for interpreting evidence collected and determining the level of process skills in students.
- The answers to these questions are either yes or no. Sometimes it becomes difficult to say yes or no to these questions.
- The answers to these questions will help the teacher diagnose the level of development for a particular process skill.
- The evidence gathered will subsequently help the teacher to guide the student to the next level of development.

Cont’d

- For example, Exploratorium (2006) compare the prediction of two students relating to a problem.
- One of the students is at the early stage of development and the other is at the later stage of development.
- The student at the early stage of development says “I think it will rain. I see clouds”.
- The students may not be able to explain why it might rain if he/she sees clouds but there is some evidence for the prediction.

Cont’d

- However, the student at the later stage of development might say that “I made this prediction because I have seen this pattern before, and that makes me think that what I predicted is really going to happen.”
- This student can justify a prediction in terms of a pattern in evidence or an idea that might explain it such as “I think it will rain because every time I see dark clouds, it rains”.
- Using the indicators in Table one, the teacher will easily know the level of development of prediction skills in the former student and guide him to effectively develop the skill of prediction

Table 1: Indicators of science process skill development

Process skills	Indicator
Observing	• Succeed in identifying obvious differences and similarities between objects and materials? • Make use of several senses in exploring objects or materials? • Identify differences of detail between objects or materials? • Identify points of similarity between objects, where differences are more obvious than similarities? • Choose to use aids to the senses (such as a hand lens or microscope) for study of details as necessary? • Distinguish from many observations those which are relevant to the problem at hand?

Cont’d

Hypothesizing/ Explaining	• **Attempt to give an explanation consistent with evidence, even if only in terms of the presence of certain features or circumstances?** • **Attempt to explain things in terms of a relevant idea from previous experience, even if they go no further than naming it?** • **Suggest a mechanism for how something is brought about, even if it would be difficult to check?** • **Show awareness that there may be more than one explanation that fits the evidence?** • **Give explanations which suggest how an observed effect or situation is brought about, and which could be checked?** • **Show awareness that all explanations are tentative and never proved beyond doubt?**

Cont’d

Predicting	• **Attempt to make a prediction relating to a problem, even if it is not derived from the evidence?** • **Make some use of evidence in making a prediction rather than basing it on preconceived ideas?** • **Make reasonable predictions which fit the evidence without necessarily being able to make the justification explicit?** • **Explain how the evidence has been used in making predictions?** • **Justify a prediction based on patterns in information or observations (such as making interpolations or extrapolations?** • **Justify a prediction in terms of an idea that might explain it?**

Cont’d

Raising Questions	• Readily ask a variety of questions, including those that can and cannot be investigated? • Participate effectively in discussing how their questions can be answered? • Recognize a difference between an investigable and a non-investigable question? • Suggest how answers to questions of various kinds can be found? • Choose a realistic way of measuring or comparing things to obtain a result? • Help in turning their own questions into a form that can be tested?

Cont’d

Planning and conducting investigations/ experiments	• **Start with a useful general approach even if details are lacking or need further thought?** • **Have some ideas of the variable that has to be changed or what different things are to be compared?** • **Keep the same the things which should not change for a fair test?** • **Have some idea beforehand of what to look for to obtain a result?** • **Choose a realistic way of measuring or comparing things to obtain a result?** • **Take steps to ensure that the results obtained are as accurate as they can reasonably be?**

Cont’d

Interpreting	• **Discuss what they find in relation to their initial questions?** • **Compare their findings with their earlier predictions?** • **Notice associations between changes in one variable and another?** • **Identify patterns or trends in their observations or measurements?** • **Check any patterns or trends against all the evidence?** • **Draw conclusions which summarize and are consistent with all the evidence?**

Cont’d

Communicating	• **Talk freely about their activities and the ideas they have, with or without making a written record?** • **Listen to others’ ideas and look at their results?** • **Report events in drawings, writings, models, paintings, and so on?** • **Use tables, graphs, and charts to record and report results when these are suggested?** • **Regularly and spontaneously use information from books (or other resources) to check or supplement their investigations?** • **Choose a form for recording or presenting results which is both considered and justified?**

Self-Assessment Questions

- Describe two ways to assess science process skills
- Describe three indicators each to consider in assessing any three named process skills.

THANK YOU