UNIT 6

HOW SCIENTISTS WORK

OUTLINE

- Meaning of scientific investigation
- Professional skills for scientists
- Conducting scientific investigations
- Inductive and deductive reasoning
- Problem solving
- Scientific ideas

OVERVIEW

- This unit will take you through the features of a science investigation that would best support student learning.
- It will cover topics such as professional skills that scientists need, how to conduct scientific investigations, problem solving and scientific ideas.
- We know you will surely enjoy every bit of it. Please take your time to read through the unit.

What is Scientific Investigation?

- A scientific investigation is the process of asking questions and then finding answers to them.
- The scientist will have to develop a plan and then implement the plan to probable answers to the question.
- Sometimes, no clear answers are found so it becomes difficult to make conclusions.
- However, the unclear answer may be useful in the future.
- A scientific investigation may be repeated as often as needed to reach a valid conclusion based on observation and experimentation.
- The conclusion drawn from a scientific investigation may lead to more questions to be investigated.
- A scientist is never done searching for answers because scientific knowledge is tentative.

Terminologies used in Scientific Investigation

- **Variables**: The characteristic or phenomenon that can be measured or classified is called a variable. It is anything that can vary or change. It is also an entity that can take on different values in different persons, places, or things. There are basically four types of variables. These are quantitative and qualitative variables, independent and dependent variables, intervening variables and extraneous variables.
- **Quantitative Variables:** A quantitative variable is one whose value results from counting or measuring something. It is one that can either be measured or counted. Examples are height, weight, number of items.

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- **Qualitative Variable:** Qualitative variables are not numerical. They are variables that are not measurement variables. They fit into categories. Examples are eye colour (blue, green brown, hazel), religion (Christianity, Islam, Buddhism), political party (New Patriotic Party, National Democratic Party, Conventional Peoples’ Party), and profession (teaching, engineering, nursing).
- **Independent Variable** : An independent variable is the variable that the scientist believes will influence the outcome measure. It is the variable that is manipulated by scientist. In other words it is the variable whose effect the scientist is interested in.

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- **Dependent Variable:** The dependent variable is the variable that the scientist presumes to be affected by the independent variable. A dependent variable is the variable that is dependent on or influenced by the independent variable(s). It is the variable that acts in response to the manipulation of the independent variable. For example, if you are studying the effect of a new educational program on student achievement, the program is the independent variable and your measures of achievement are the depended variables
- **Intervening Variables**: An intervening variable is the variable that links the independent and dependent variable. For example, if you are studying the effect of a new teaching method on student achievement, and the medium of teaching is English Language, then the intervening variable is the English Language.

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- **Extraneous variables:** An extraneous variable is a variable that the scientist is not intentionally studying in the experiment but has the potential to affect the results of the experiment. When you conduct a study you are looking to see if one variable (the independent variable) has an effect on another variable (the dependent variable). All variables which are not the independent variables, but could affect the results of an experiment or the dependent variable are extraneous variables.
- **Constants**: Constants are all the factors in the experiment that are not allowed to change throughout the entire experiment. Controlling constants is very important to assure that the results are due only to the changes in the independent variable. Everything, except the independent variable, must be constant in order to provide accurate results.

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- **Experimental group:** The experimental group is the group(s) being tested with the independent variable. Each experimental group has only one factor different from each other, everything else must remain constant.
- **Control group:** The control group is a standard of comparison for checking or verifying the results of an experiment where all variables must be held constant.

Types of Scientific Investigation

- Descriptive Investigation
- Comparative Investigation
- Experimental Investigation

Experimental Investigation

- Experimental investigation is the type of scientific investigation where the independent variable(s) is/are manipulated and applied to the dependent variable(s) to measure their effect.
- This type of investigation may include an experimental group/subject and a control group/subject and is basically designed to test the hypothesis.
- Experimental investigations involve a process in which variables are actively manipulated, controlled, and measured in an effort to gather evidence to support or refute a causal relationship.
- Experimental investigations have a control group which does not receive any treatment.

Descriptive Investigation

- Descriptive investigation is an investigation in which scientific questions are investigated and observations of phenomena are recorded and catalogued.
- In this type of investigation, the scientist uses careful observations and measurements to develop descriptive findings about an organism, substance, reaction, or natural process.
- It does not include formulation of hypothesis.
- This investigation can include both quantitative and/or qualitative data.

Comparative Investigation Questions

- Comparative investigation is an investigation where observations are made that compare two objects or phenomena.
- Comparative investigations involve collecting data on different organisms/objects/features, or collecting data under different conditions (e.g., times of year, temperatures, locations) to make a comparison.
- In comparative investigations scientists look for patterns or trends by comparing similarities and differences over time and under various circumstances.
- It does not include control groups.

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- Identifying the boiling points of three different liquids and using a hand lens to observe the external anatomy of two different insects are examples of comparative investigations.
- This type of investigations involves investigations such as:
  - collecting data on different organisms/objects/features, or collecting data under different conditions (e.g., times of year, temperatures, locations) to make comparisons.
  - looking for patterns or trends by comparing similarities and differences over time and under various circumstances.
  - include the following parts of scientific inquiry: observations, scientific research question, hypothesis, procedure, variables (independent and dependent), data, graphs, analysis and conclusions.

Self-Assessment Questions

- Explain scientific investigation.
- Describe at least four terminologies used in scientific investigations.
- Differentiate between comparative and experimental investigations.
- Describe two similarities between comparative and experimental investigations.

Professional Skills all Scientists need

- The most important traits in any career are the desire and will to pursue and excel within it.
- It can be argued that certain personal qualities are more or less valuable to a scientist, but any such list will always be subjective.
- The best that can be done is to find some commonalities in the skills and environment across varied scientific disciplines and determine what qualities may be best suited to those skills and surroundings.
- For science to be sustainable, all entities involved in the scientific enterprise must be able to recruit, train and retain scientists who can adapt to the evolving needs of the scientific workforce and society.

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- Scientists working in academic and industry labs, in policy and in communications all have made valuable contributions to the fight against diseases, improvement in life of individuals, technological advancements etc.
- To thrive in their future careers, scientists, trainees need to learn both technical and professional skills from experimental design to written and verbal communication to specific scientific techniques to working in diverse teams.
- Companies in every industry want to hire well-rounded individuals with a balanced mix of technical expertise and professional skills, and the field of biotechnology is no different.
- Biotechnology focuses on the intersection of biology and technology, and the development of new products that are designed to improve people's health.

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- For example, professionals in this field might focus on advanced therapies, stem cell and gene therapy, or biopharmaceuticals.
- While the skills needed to become a biotechnologist are scientific and technical, companies today are focused on hiring individuals who demonstrate strong soft skills above all else. Soft skills include competencies like communication, social skills, and attitudes.
- “Scientists have a reputation for being quirky and keeping to themselves,” he says. “That’s okay if you’re going to become an academic researcher, but most students are preparing to go into industry. The number one thing we hear from employers is that they want someone who fits into their business culture.”
- According to LinkedIn’s 2019 Global Talent Trends report, 92 percent of talent professionals and hiring managers consider soft skills to be just as important or more important than hard skills.

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- In fact, the report concluded that 89 percent of bad hires were found to have poor soft skills.
- This is a prevalent concern at life science companies, according to research.
- Hiring managers are becoming increasingly concerned with finding individuals who not only possess the technical knowledge, but the skills to help implement strategies, develop industry partnerships, and lead a product or organization to success.
- More than ever, companies today are placing a high value on soft skills like teamwork, business acumen, critical thinking, and problem-solving.

Examples of Key Soft Skills

- Communication
- Teamwork
- Business Acumen
- Self-Motivation
- Adaptability
- Management Skills
- Mentoring
- Critical Thinking and Problem Solving
- Curiosity
- Reasoning
- Interpersonal Skills
- Creativity
- Independent learning

Communication

- As science becomes increasingly interdisciplinary, professionals in this field must be able to distill complex topics into concepts that are easily understood by lay audiences.
- Scientists also need to hone interpersonal communication skills, which are necessary when collaborating with fellow scientists.
- Developing these abilities will be especially important for giving presentations, networking at industry conferences, and working in teams.

Teamwork

- Science is a collaborative field.
- Scientists need to work well with others and navigate conflicts and differences of opinion.
- Being a team player is also about knowing when to step up as a leader and when to step back and take direction from someone else.
- To be a good team player you need to be versatile and nimble.
- You need to be a good listener and really hear what people are saying to you, process it, and execute on what they're asking.

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- Research is inherently a collaborative activity.
- It requires you to partner with your lab mates, your research mentor, other research groups and core facilities, among others.
- Business activities are collaborative too.
- Being able to outline your role and duties in a group project clearly, execute your tasks, report your progress and see how your piece fits into the bigger picture are all important teamwork skills you pick up while working in a research lab.

Business Acumen

- While it's important to have a strong technical background, it's equally as important to have an understanding of the business behind science beyond your day-to-day responsibilities.
- Scientists should have an understanding of financial and regulatory changes that influence the sector, the broader business's goals and challenges, and trends that could affect the future of the industry and the future of the company.

Self-Motivation

- According to research, employers value people who are able to self-start and take the initiative to get work done.
- This skill is a huge benefit to a company.
- Directing people takes time away from getting work done.
- If I'm your boss, I don't want to have to tell you what to do all the time. I want to be able to trust that you can get work done on your own."

Adaptability

- Science is a dynamic industry that's evolving at breakneck speed.
- Scientists need to be flexible and constantly adapt to new information, tools, and protocols.
- Science will be completely different five years from now.
- There will be new ways of doing things, so you can never get comfortable.
- You have to constantly evolve and adapt, and be comfortable with change.

Management Skills

- Great scientists will exemplify a variety of management skills.
- Not only is it important to know how to manage, store, visualize, and analyze large scientific data sets, it's also important to know how to manage variables like your time, your work, and a successful team.

Critical Thinking and Problem Solving

- The science industry relies on innovation and values employees who can solve problems quickly.
- The best scientists are able to address and prioritize problems, then work to find the right solution.
- Scientists know the end goal and they know the tools that are at their disposal, but what they don't know is what it will take to get to that end.
- In that process, you're going to try new things, troubleshoot, and try again.

Curiosity

- The scientific method is a system of asking questions, making speculations, observing and drawing conclusions; a method applied in some form or another to most scientific fields.
- To this end, scientists who are naturally inquisitive have an advantage, as they will, in a sense, apply the scientific method to what they see and observe with little prompting.
- Whether an astronomer behind a telescope or a biologist in the field, an inclination to ask questions about observations can only help in scientific pursuits, especially when questions lead to further questions and begin opening up new avenues of investigation.

Reasoning

- An analytical mind is a boon to a scientist of any discipline.
- Scientists often work with large amounts of collected data and, especially in fields such as physics and atmospheric science, they must also contend with complex mathematical equations on a regular basis.
- The ability to correlate data accurately, draw reasonable conclusions and avoid errors in calculations is vital for a scientist.
- Inaccuracies or findings based in unsound science can have far-reaching consequences, especially among those who may be called to predict likely outcomes based on their data and calculations, such as meteorologists and astronomers

Interpersonal Skills

- Most scientists work as a team at least part of the time, making cooperation and interpersonal skills necessary for success.
- Some scientists, such as meteorologists and zoologists, additionally have frequent cause to interact with the public, making communication skills of even higher priority.
- Cooperation, effective communication, and the ability to work toward a common goal with others represent a suite of traits necessary for all scientists to share.
- Without it, large projects and correlating shared data across disciplines becomes much harder.

Creativity

- Creativity is not always considered among the traits a scientist needs, but its importance should not be underestimated.
- The purpose of scientists is to confront very large and complex problems, and it takes a creative mind to extrapolate solutions from gathered data, research and experimentation.
- This may take many forms: finding a way for humans to coexist peacefully with an endangered habitat; making an intuitive leap in understanding the significance of a new space anomaly; conceiving a new method of utilizing an underused chemical material; or many other out-of-the-box solutions scientists have created over the centuries.
- It is difficult to gauge or quantify this sort of inspiration, but when it appears, it is among the most valuable of a scientist's traits

Independent learning

- Most scientists naturally are driven to learn and are able to seek out information for themselves.
- Being self-directed in your learning and knowing where and how to find new knowledge is essential in any field.
- If you can motivate yourself to learn, you'll quickly catch up in your new business role.
- Additionally, when you're starting a new project, you're able to gain independence more quickly, showing your value to your new business team

Mentoring

- Mentoring is another key skill to cultivate.
- It's especially important for scientists in teaching and advisory positions, and it's essential for anyone seeking a leadership or management role.
- But mentoring others isn't the only aspect of mentoring that matters; learning how to be mentored is important, too.
- The support and guidance of more established scientists—and also peers—will greatly facilitate your career progress.

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- So if you're not already comfortable reaching out to others for assistance and advice, you should look for opportunities to do this and begin forging relationships with potential mentors.
- No matter what path you take, at some point you'll have to navigate a difficult conversation.
- This might include asking for a promotion or raise, negotiating your start-up package, or resolving a dispute with a co-worker.
- Skilled communicators handle these conversations with confidence, grace, and diplomacy. Soft skills aren't innate, they're learned through practice and experience.

Self-Assessment Questions

- Describe six professional skills that scientists need.

Steps for Conducting Scientific Investigations

- Step 1: Make observations
- Step 2: Formulate investigation questions
- Step 3: Formulate hypothesis
- Step 4: Plan the investigations
- Step 5: Test your hypothesis (and collect data)
- Step 6: Analysis of data
- Step 7: Draw conclusions
- Step 8: Communicate results

Step 1: Make observations

- The first and foremost step of a scientific investigation is to make observations.
- During the observation scientists define the problem and conduct research.
- First, a broad topic is selected concerning some topic or a research question is asked.
- The scientist researches the question to determine if it has been answered or the types of conclusions other researchers have drawn and experiments that have been carried out in relation to the question.
- Research involves reading scholarly journal articles from other scientists, which can be found on the Internet via research databases and journals that publish academic articles online.
- During research, the scientist narrows down the broad topic into a specific research question about some issue.

Step 2: Formulate investigation questions

- In this step, you have to write an experimental question.
- This question should include the manipulated and responding variables of the investigation.
- Example: When (manipulated variable) is changed, what happens to (responding variable)? There must be a question that needs an answer.
- Based on the situation presented there is something to find out, which may either be what, how, when, where or why.

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- It must be noted that investigations vary depending on the scientific question.
- A typical question could be: “What causes a dog to bark?” Equipping yourself with knowledge on the subject area, and looking at similar investigations on the topic will prove useful.
- This provides the background to move on to the next step.
- In this step, you have to pose a question.
- The question should be rudimentary, and the motive behind the question should be clear to you as it will help you narrow down the possibilities.

Step 3: Formulate hypothesis

- Write a hypothesis.
- A hypothesis is a prediction of what may happen in the investigation based on prior knowledge.
- Example: If (the manipulated variable is changed somehow), then (what you predict will happen to the responding variable), because (why you think so).
- Based on your preliminary research you may come up with an answer to the question.

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- The answer you have arrived at will become your hypothesis for this investigation, which will be tested by an experiment or simple observation.
- You need to write your question as a hypothesis (an educated guess or prediction about what you expect to happen).
- For example, in an investigation with the question 'Does the amount of light affect the growth of seedlings?', your hypothesis could be: 'The amount of light affects the growth of seedlings.'
- Your hypothesis should be informed by your background knowledge and research.

Step 4: Plan the investigations

- The scientist will then have to plan how to conduct the investigation and gather all the materials needed.
- The procedures must be clearly described.
- In the planning stage of your investigation, you decide on all the different requirements or apparatus needed to perform your experiment or observation, and exactly how you will proceed.
- To ensure an accurate result you may use more persons in the investigation to prove your hypothesis.
- Your investigation will run smoothly with careful planning.

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- Generally, the tools and equipment used in a scientific investigation will vary based on the experiment.
- Some common tools used in experiments are a timer, thermometer, scale, telescope, measuring container, light source, water, pencil, note book and tape measure.
- It is important that the tools used are in proper working condition to ensure accuracy in your results.
- The steps used in a scientific investigation may also vary.
- Example, it may involve observing a pattern, such as a movement or growth rate, or it may be a case of controlling variables in a case of doing an experiment to find out if sunlight is necessary for a plant to survive.

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- Research your topic area using books, websites and experts to broaden your scientific understanding of the topic.
- Designing a scientific experiment involves planning how you are going to collect data.
- Often, the nature of the research question influences how the scientific research will be conducted.
- For example, researching people's opinions naturally requires conducting surveys.
- When designing the experiment, the scientists select from where and how the sample being studied will be obtained, the dates and times for the experiment, the controls being used and the other measures needed to carry out the research.

Step 5: Test your hypothesis (and collect data)

- In this step, you have to cross-check the matters according to your hypothesis to prove the acuteness of it.
- After this process, the hypothesis can turn out to be true or may not be.
- In the latter case, you have to propose a different hypothesis.
- So, it boils down to the trial-and-error method.
- At this stage of the investigation, you will execute your experiment and record your data.
- Your data is the information collected from the experiment and may come in various forms.

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- It may be based on a simple observation or measurements taken during the process.
- To be as accurate as possible, with certain investigations you may have to do repeat trials.
- Repeats are done if you wish to obtain an average.
- It is important to record each finding immediately as you go along.
- Data can be represented using graphs, pie charts or tables.
- Collect your data and write it down in a data table.
- Decide how many trials you will need to do, because you might need extra columns in your data table.

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- To conduct a fair test, you change only one thing (a variable).
- You need to be able to measure the change.
- Data collection involves carrying out the experiment the scientist designed.
- During this process, the scientists record the data and complete the tasks required to conduct the experiments.
- In other words, the scientist goes to the research site to perform the experiment, such as a laboratory or some other setting.
- Tasks involved with conducting the experiment vary depending on the type of research.
- For example, some experiments require bringing human participants in for a test, conducting observations in the natural environment or experimenting with animal subjects.

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- If it’s group work, teachers should take into account specific factors such as group size, group members of the same or different gender, problems to solve, and so on.
- In this regard, teachers need to be more democratic in the formation of groups.
- Also, teachers should consider the techniques and methods that will be used in teaching and learning.
- For example, teachers can use the discussion method within the group they have formed.

Step 6: Analysis of data

- Analysis is an explanation of the results of the data.
- You must complete any necessary calculations and design graphs.
- What is the best way to organise and analyse your data? Can you use tables and graphs to record the data you have collected? Are there any patterns or trends you have identified in your data? Does the data support your hypothesis?
- This is where you make interpretations of the data.
- Analyzing data for the scientific research process involves bringing the data together and calculating statistics.
- Statistical tests can help the scientist understand the data better and tell whether a significant result is found.

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- Calculating the statistics for a scientific research experiment uses both descriptive statistics and inferential statistics measures.
- Descriptive statistics describe and organize the data and samples collected, such as sample averages or means, as well as the standard deviation that tells the scientists how the data is distributed.
- Inferential statistics is basically learning about what we do not observe (parameters) using what we observe (data).
- Statistical Inference is the procedure by which we reach a conclusion about a population on the basis of the information contained in a sample drawn from that population.
- It involves conducting tests of significance that have the power to either confirm or reject the original hypothesis.

Step 7: Draw conclusions

- In this step, you have to conclude the process of the scientific investigation.
- Scientists should note that a hypothesis can never be proven entirely true as one can never examine all the possibilities.
- The more pieces of evidence you have to support the hypothesis, the more acute hypothesis you have.
- A conclusion is a summary of the investigation that refers back to both the original question and the hypothesis.
- Actual data, either numeric or observational, must be included in a conclusion.

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- At this final stage, your hypothesis may be proven correct or incorrect.
- You will provide details of your outcome, and give reasons for this result.
- If you are not very satisfied or still unsure with your result you may repeat the experiment. Make sure to discuss these things in your conclusion:
  - Was this investigation able to answer the original question? How do you know that? Include data.
  - Does the data/observations support or refute your hypothesis? Provide data in your explanation.
- Here is where you explain the science related to your investigation based on your earlier research and what happened in your experiment.

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- You need to explain your results clearly.
- What happened? Why? Describe any patterns you can see in the data you have collected. Can you explain them? Analyze the success of the method you chose. Did anything go wrong? Would you change anything if you repeated the investigation again? Can you think of any further investigations that would help answer your question more deeply?
- After the data from an experiment is analyzed, the scientist examines the information and makes conclusions based on the findings.
- The scientist compares the results both to the original hypothesis and the conclusions of previous experiments by other researchers.
- When drawing conclusions, the scientist explains what the results mean and how to view them in the context of the scientific field or real-world environment, as well as making suggestions for future research.

Step 7: Communicate results

- The study of science is aimed at making life easier for humans.
- Scientific investigations make new discoveries about the natural to direct how well humans live on earth.
- Therefore the findings of scientific investigations should be communicated across the world for others to also access the new knowledge and confirm it.
- The results obtained in the investigations are usually presented in a report form, which may be published and shared with persons across the world who may have interest in such investigation.

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- Sharing your results, based on your experiment will prompt other scientists to replicate the experiment.
- Replication of studies increases the credibility and validity of the findings.
- If the same result is obtained each time, then you can be assured that the result is correct and can be generalized a larger population.

Self-Assessment Questions

- Describe how to conduct scientific investigations.

Scientific Reasoning/Thinking

- Humans use reasoning to navigate through the world every day.
- Scientific reasoning/thinking is the process by which one identifies a problem through observation and fashions out a way to solve it.
- Scientific reasoning/thinking is procedural and encompasses core reasoning and problem-solving competencies and involves basic inference processes in forming hypotheses, designing experiments to test hypotheses, distinguishing determinate evidence from indeterminate evidence, and interpreting results as evidence that supports or refutes the hypotheses.
- Although using the scientific method is inherent to science, it is inadequate in determining what science is.

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- This is because it is relatively easy to apply the scientific method to disciplines such as physics and chemistry, but when it comes to disciplines like archaeology, paleoanthropology, psychology, and geology, the scientific method becomes less applicable as it becomes more difficult to repeat experiments. These areas of study are still sciences, however.
- Consider archaeology: even though one cannot perform repeatable experiments, hypotheses may still be supported.
- For instance, an archaeologist can hypothesize that an ancient culture existed based on finding a piece of pottery.
- Further hypotheses could be made about various characteristics of this culture.
- These hypotheses may be found to be plausible (supported by data) and tentatively accepted, or may be falsified and rejected altogether (due to contradictions from data and other findings).

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- Scientific reasoning is important not just for institutional scientific research.
- It is true that scientists use specialized theories (e.g., quantum physics) which non-scientists do not have to use in everyday life.
- But many of the principles of reasoning (e.g., rules for identifying causes) are applicable also to everyday life.
- Even if we are not scientists, we need to make use of good reasoning to explain, predict, and control the events around us.

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- When we want to jumpstart our career, protect our investments, improve our health, we need to gather evidence to find an effective way which is likely to achieve our aims.
- In all these cases, good scientific thinking skills help.
- Reasoning is based on previous established facts.
- To establish a new fact or truth one has to put it on test of reasoning.
- If the new fact coincides with the previously established facts, it is called logical or rational.
- Logical reasoning is beyond subjectiveness.

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- In the process of logical reasoning, we approach everything with a question mark in our mind.
- For each question we make a hypothesis and this hypothesis is tested empirically or theoretically with the help of previously proved or established truths or facts.
- In mathematical working we also move upwards by the process of reasoning
- Scientific thinking refers to both thinking about the content of science and the set of reasoning processes that permeate the field of science: induction, deduction, experimental design, causal reasoning, concept formation, hypothesis testing, and so on.

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- Here we cover both the history of research on scientific thinking and the different approaches that have been used, highlighting common themes that have emerged over the past 50 years of research.
- Future research will focus on the collaborative aspects of scientific thinking, on effective methods for teaching science, and on the neural underpinnings of the scientific mind.
- Scientists seek to understand the world and the way it operates.
- To do this, they use two methods of logical thinking: inductive reasoning and deductive reasoning.

Inductive Reasoning

- Inductive reasoning is a form of logical thinking that uses related observations to arrive at a general conclusion.
- This type of reasoning is common in descriptive science.
- A life scientist such as a biologist makes observations and records them.
- These data can be qualitative or quantitative and the raw data can be supplemented with drawings, pictures, photos, or videos.
- From many observations, the scientist can infer conclusions (inductions) based on evidence. Inductive reasoning involves formulating generalizations inferred from careful observation and the analysis of a large amount of data. Brain studies provide an example.

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- In this type of research, many live brains are observed while people are doing a specific activity, such as viewing images of food.
- The part of the brain that “lights up” during this activity is then predicted to be the part controlling the response to the selected stimulus; in this case, images of food.
- The “lighting up” of the various areas of the brain is caused by excess absorption of radioactive sugar derivatives by active areas of the brain.
- The resultant increase in radioactivity is observed by a scanner.
- Then researchers can stimulate that part of the brain to see if similar responses result.

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- Generally human knowledge arises from observations and experiences.
- In the beginning mathematics also arises out of practical applications and it is mostly inductive and intuitive.
- When the statements or propositions are based on general observations and experiences, the reasoning is called inductive.
- From our observation we can get that some particular properties hold good in the sufficient number of cases and by this we may conclude that these properties will also hold in all other similar cases.
- This type of logical reasoning is called inductive reasoning.

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- Here inductive means that a particular theme, theory, rule, formulae is induced from general experience or observation.
- Thus, in inductive reasoning we proceed from several particular examples or experiences to a general agreement.
- In mathematics this type of reasoning is very much used.
- In inductive reasoning, there are certain possibilities that the conclusion drawn can be false, even if the all the assumptions are true.
- The reasoning vests on experience and observations that support the apparent truth of the conclusion.
- Further, the argument can be strong or weak, as it only describes the likelihood of the inference, to be true.

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- Inductive reasoning is a form of reasoning that arrives at a conclusion based on patterns and observations.
- If used by itself, inductive reasoning is not an accurate method for arriving at true and accurate conclusions.
- Take the example of three friends: Jim, Mary and Frank. Frank observes Jim and Mary fighting. Frank observes Jim and Mary argue three or four times during the week, and each time he sees them, they are arguing.
- The statement, "Jim and Mary fight all the time," is an inductive conclusion, reached by limited observation of how Jim and Mary interact.
- Inductive reasoning can lead students in the direction of forming a valid hypothesis, such as "Jim and Mary Fight often." But inductive reasoning cannot be used as the sole basis to prove an idea.

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- Inductive reasoning requires observation, analysis, inference (looking for a pattern) and confirming the observation through further testing to arrive at valid conclusions.
- Inductive reasoning is the act of using specific scenarios and making generalized conclusions from them. Also referred to as “cause-and-effect reasoning,” inductive reasoning can be thought of as a “bottom up” approach.
- For example, you might observe that your older sister is tidy, your friend’s older sister is tidy and your mom’s older sister is tidy. Inductive reasoning would say that therefore, all older sisters are tidy.
- In psychology, inductive reasoning or 'induction' is defined as reasoning based on detailed facts and general principles, which are eventually used to reach a specific conclusion.

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- Also known as inductive logic or the bottom-up approach, induction is basically a type of reasoning wherein the chances of the conclusion being false are significant even when all the premises, on which the conclusion is based, are true.
- As opposed to deductive reasoning, which goes from general to specific, inductive reasoning goes from specific to general.
- In other words, it begins with a specific argument and arrives at a general logical conclusion.
- At times, induction is termed as strong, or weak, on the basis of the credibility of the argument put forth.

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- Some examples of inductive reasoning are:
  - Determining when you should leave for work based on traffic patterns
  - Rolling out a new accounting process based on the way users interact with the software
  - Deciding on incentive plans based on an employee survey
  - Changing a meeting time or format based on participant energy levels
  - The coin I pulled from the bag is a penny. That coin is a penny. A third coin from the bag is a penny. Therefore, all the coins in the bag are pennies.

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- "Harold is a grandfather. Harold is bald. Therefore, all grandfathers are bald." The conclusion does not follow logically from the statements.
- Here is an example of using inductive reasoning in everyday life.
- My father and mother are short, therefore, I will be short.
- All the sheep this scientist has seen are white, therefore, all sheep are white.
- Classical music did not raise my student's test grades, therefore, classical music does not help students learn.

Cont’d

- The conclusion in each of these examples is wrong, as there is other evidence outside personal observations that make these untrue. Therefore, these examples would be considered "weak" arguments.
- However, there is an easy solution to make each of these conclusions stronger by making it more credible such as:
  - Therefore, I will most likely be short.
  - Therefore, most sheep must be white.
  - Therefore, classical music did not help my students learn this lesson.

Cont’d

- An example of a strong example of inductive reasoning is found below:
- All the tigers observed in a particular region have black stripes on orange fur.
- Therefore, all the tiger’s native to this region has black stripes on orange fur.
- Even though all the tigers that were observed in this region sported black stripes on orange fur, the existence of a white tiger cannot be ruled out.
- Based on this, one can assume that the conclusion mentioned in this example is not certain.
- But then, the chances of coming across a white tiger are actually very rare, and that in itself makes this statement a good example of strong induction.

Cont’d

- In other words, a strong induction is the one wherein the conclusion is backed by the premises to a significant extent.
- There are multiple reasons to use inductive reasoning, including:
- **Everyday Life:** Used to draw conclusions about the world from daily personal experiences.
- **Scientific Method**: Used by scientists or individuals to create a hypothesis after making observations before further testing the outcomes.
- **Academic Life:** Although inductive arguments can potentially yield weak conclusions, it is also the primary reasoning in an academic setting.

Types of Inductive Reasoning

- Inductive generalization
- Simple induction
- Causal inference
- Argument from analogy, and
- Statistical syllogism.

Cont’d

- **Inductive Generalization**: This type reasoning uses premises about a sample set to draw conclusions about a whole population. An example is all observed people are right-handed, therefore all the people are right-handed.
- **Simple Induction:** All the dogs that have been observed, can bark, therefore all the dogs can bark.
- **Causal Inference**: This type of reasoning includes a causal link between the premise and the conclusion. For instance: “There have always been swans on the lake in summer, therefore the start of summer will bring swans onto the lake.”. Joe leaves home at 08:30 in the morning and arrives late for work, based on which he concludes that he will be late for work every time he leaves at 08:30. 29

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- **Argument from Analogy**: This form notes that on the basis of shared properties between two groups, they are also likely to share some further property. For example: “Swans look like geese and geese lay eggs, therefore swans also lay eggs.” John and Joe are friends. John likes to sing, write and read. Joe likes to sing and write. Therefore, one assumes that Joe also likes to read.
- **Statistical Syllogism** : One common type of deductive reasoning is known as a syllogism. Syllogisms almost always appear in the three-line form, with a common term that appears in both premises but not the conclusion. . This form uses statistics based on a large and random sample set, and its quantifiable nature makes the conclusions stronger. For example: “95% of the swans I’ve seen on my global travels are white, therefore 95% of the world’s swans are white.” John plays as a pitcher for his team. All pitchers pitch at an average speed of 90 MPH, therefore John pitches at an average speed of 90 MPH as well.

Improving Inductive Reasoning Skills

- **Develop your attention to detail**: Make observations daily and develop your ability to notice smaller details about situations around you. For instance, you can set a goal to observe specific details in the office, such as the number of staff members who wear watches, to better train yourself to notice information going on around you. As you make more observations and develop your attention to detail more proficiently, you can better develop logical conclusions that can support your career performance and advancement.
- **Ask questions and make inferences**: Seek input from colleagues and your superiors and use the feedback to draw conclusions about specific tasks, projects or processes that can help you increase your productivity or improve your performance. Ask questions when you need clarification so you can better understand cause-and-effect relationships in your work environment. For instance, using inductive logic may mean postponing a meeting because multiple team members are absent and unable to attend. The observations you make include absent employees and the inference you can come to is that it's beneficial for the team to delay the meeting.

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- **Improve your knowledge**: Expand your knowledge to better form connections between observations and information in your work environment. For instance, attend industry workshops, professional development programmes and other educational events that help you learn new skills, apply new concepts and advance your knowledge. With more awareness of your role and abilities, you can equip yourself more efficiently to take action and achieve successful results at work.
- **Solve smaller parts of complex problems**: When making observations and drawing conclusions, try splitting more complex problems or processes into smaller parts. This can help you focus on the most important details necessary to make informed decisions, plan strategies and take action in your work. When you focus on small parts of a larger concept, you will be better able to form logical conclusions that help you achieve goals.

Deductive Reasoning

- In deductive reasoning we proceed from general to a specific.
- This type of reasoning is based on self-evident truth, established facts, postulates and axioms etc.
- Here a particular statement or proposition is proved with the help of already established general rules.
- Therefore, in deductive reasoning we proceed from a premise.
- We make several statements or propositions in our mind.
- This reasoning consists in comparing the statements and drawing a conclusion from them.

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- Thus, here we deduce the solution or proof of a particular problem or statement on the basis of a general premise.
- In mathematics, the inductive reasoning is useful for beginners but, afterward mostly deductive reasoning is more fruitful.
- As-far-as the place of inductive and deductive is concerned,’ the following saying is good enough to clear it.
- “Mathematics in the making is not a deductive science, it is an inductive, experimental science and guessing is the tool of mathematics. Mathematicians like all other scientists, formulate their theories form bunches, analogies and simple examples. They are pretty confident that what they are trying to prove is correct, and in writing these, they use only the bulldozer of logical deduction”.

Cont'd

- Deductive reasoning or deduction is the type of logic used in hypothesis-based science.
- In deductive reason, the pattern of thinking moves in the opposite direction as compared to inductive reasoning.
- Deductive reasoning is a form of logical thinking that uses a general principle or law to forecast specific results.
- From those general principles, a scientist can extrapolate and predict the specific results that would be valid as long as the general principles are valid. Studies in climate change can illustrate this type of reasoning.
- For example, scientists may predict that if the climate becomes warmer in a particular region, then the distribution of plants and animals should change.

Cont’d

- These predictions have been written and tested, and many such predicted changes have been observed, such as the modification of arable areas for agriculture correlated with changes in the average temperatures.
- Deductive reasoning is the act of making a generalized statement and backing it up with specific scenarios or information.
- It can be thought of as a “top down” approach to drawing conclusions.
- For example, consider the statement “all apples are fruits.” When you introduce specific piece of information like “all fruits grow on trees”, you can then deduce that all apples grow on trees.
- Another classic example of deductive reasoning is the following formula: If A = B and B = C, then A must equal C

Cont’d

- Deductive reasoning is a step-by-step, logical approach to proving an idea by observation and testing.
- The deductive reasoning starts with an initial, proven fact and builds an argument one statement at a time to undeniably prove a new idea.
- A conclusion arrived at through deductive reasoning is built on a foundation of smaller conclusions that each progress toward a final statement.
- Deductive reasoning, or deductive logic, is a type of argument used in both academia and everyday life.
- Also known as deduction, the process involves following one or more factual statements (i.e. premises) through to their logical conclusion.

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- In a deductive argument, if all the premises are true, and the terms correctly applied, then it holds that the conclusion will also be true.
- This is alternatively referred to as "top-down" logic because it usually starts with a general statement and ends with a narrower, specific conclusion.
- The general principles of deductive reasoning date back to the Ancient Greek philosopher Aristotle.
- Deductive reasoning is also at the heart of mathematics and computer programming.
- Deduction is generally defined as "the deriving of a conclusion by reasoning." Its specific meaning in logic is "inference in which the conclusion about particulars follows necessarily from general or universal premises."

Cont'd

- Deduction is generally defined as "the deriving of a conclusion by reasoning."
- Its specific meaning in logic is "inference in which the conclusion about particulars follows necessarily from general or universal premises."
- Simply put, deduction—or the process of deducing—is the formation of a conclusion based on generally accepted statements or facts.
- It occurs when you are planning out trips, for instance. Say you have a 10 o'clock appointment with the dentist and you know that it takes 30 minutes to drive from your house to the dentist's.
- From those two facts, you deduce that you will have to leave your house at 9:30, at the latest, to be at the dentists on time.

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- If a sandwich is defined as "two or more slices of bread or a split roll having a filling in between," and a hot dog is defined as "a frankfurter; especially: a frankfurter heated and served in a long-split roll" then one must deduce that any hot dog served in a split roll is a sandwich.
- Other examples of deductive reasoning include:
  - Developing a marketing plan that will be effective for a specific audience
  - Designing the floor plan and layout of a shop to maximize sales
  - Planning out a budget to get the highest output from your investments
  - Determining the most efficient ways to communicate with clients
  - Using reasoning during the hiring process

Types of Deductive Reasoning

- **Syllogism**: One common type of deductive reasoning is known as a syllogism. Syllogisms almost always appear in the three-line form, with a common term that appears in both premises but not the conclusion. Here is an example:
  - If a person is born in the 1970s, they're in Generation X.
  - If a person is in Generation X, then they listened to music on a Walkman.
  - Therefore, if a person is born in the 1970s, then they listened to music on a Walkman.

Cont’d

- **Modus Ponens**: Another type of deductive reasoning is known as modus ponens and it follows this pattern:
  - If a person is born between 1981 and 1996, then they’re a millennial.
  - Miley was born in 1992.
  - Therefore, Miley is a millennial.
- This type of reasoning is also known as “affirming the antecedent,” because only the first premise is a conditional statement, and the second premise merely affirms that the first part of the previous statement (the antecedent) applies.

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- **Modus Tollens**: Yet another type of deductive reasoning is modus tollens, or "the law of contrapositive." It is the opposite of modus ponens because its second premise negates the second part (the consequent) of the previous conditional statement. For example:
  - If a person is born between 1981 and 1996, then they're a millennial.
  - Bruce is not a millennial.
  - Therefore, Bruce was not born between 1981 and 1996.

Improving Deductive Reasoning Skills

- **Use the elimination process**: When testing generalisations or making decisions for the best outcomes, consider applying the elimination method. With this process, you eliminate different options of the scenario or choice that do not support the outcome you're trying to achieve. The method also seeks to eliminate irrelevancy by focusing only on pertinent details and ideas that can help you form accurate conclusions.
- **Form a hypothesis**: Take inductive reasoning further and develop a hypothesis from observations that you can test. For example, if you observe colleagues using the same printer when printing financial documents, you can form a hypothesis about the quality of the printing, ink or another aspect of the equipment. Then, you can use the information you gather from your observations to focus on a single hypothesis to test. In this case, you might form a hypothesis about the ink causing changes in the print quality.

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- **Be aware of patterns:** When making observations and drawing conclusions that can help you form a hypothesis, it's also important to develop your ability to notice patterns in your environment. For instance, observing a species of bird during the same season each year can give you insight into the birds' migratory patterns. Practice forming cause-and-effect relationships and notice when patterns are present in your observations to better develop strategies for testing conclusions and improving your ability to apply deductive reasoning.
- **Focus on relevant details**: Observing events and different scenarios in your environment can often mean noticing both relatable and irrelevant details about the inferences you make. Therefore, it's important to focus only on details that can support your logic and methods of evaluation. For example, analysing financial documents to test a hypothesis about the causes of market share increases would not require the number of employees who are currently on the production floor. The more you improve your awareness of relevant details, the more you can improve your deductive reasoning skills.

Similarities between Deductive and Inductive reasoning

- Induction and deduction are somehow similar in the sense that both give much emphasis on the likelihood of the conclusion's being true if the premises were true, that is, the support that the premises provide for the conclusion.
- We have learned that in a valid deductive inference, the premises support the conclusion in such a way that it would be impossible for the premises of an argument to be true and for its conclusion to be false. This spells its sharp contrast to induction, for the truth of the premises of an inductive argument does not guarantee the truth of its conclusion.
- Going back to our example, even though it is true that grasshoppers have invaded our rice plants for years, it remains possible that grasshoppers would not destroy our farm this summer, or never reappear at all.

Differences between Inductive and Deductive Reasoning

- The argument in which the premises give reasons in support of the probable truth of the conjecture is inductive reasoning. The elementary form of valid reasoning, wherein the proposition provides the guarantee of the truth of conjecture, is deductive reasoning.
- While inductive reasoning uses the bottom-up approach, deductive reasoning uses a top-down approach.
- The initial point of inductive reasoning is the conclusion. On the other hand, deductive reasoning starts with premises.
- The basis of inductive reasoning is behaviour or pattern. Conversely, deductive reasoning depends on facts and rules.

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- Inductive reasoning begins with a small observation, that determines the pattern and develops a theory by working on related issues and establish the hypothesis.
- In inductive reasoning, the argument supporting the conclusion, may or may not be strong. On the contrary, in deductive reasoning, the argument can be proved valid or invalid.
- Inductive reasoning moves from specific to general. Unlike, deductive reasoning moves from general to particular.
- In inductive reasoning, the inferences drawn are probabilistic. As opposed, in deductive reasoning, the generalizations made are necessarily true, if the premises are correct.

Applications of Inductive and Deductive Reasoning

- Deduction can also be temporarily used to test an induction by applying it elsewhere.
- A good scientific law is highly generalized like that in Inductive reasoning and may be applied in many situations to explain other phenomena.
- Deductive reasoning is used to deduce many experiments and prove a general rule.
- Deductive and inductive reasoning are both methods of reaching logically true conclusions used in scientific research as well as everyday life. Very often, they are confused. That is why a clear distinction between them should be made.

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- As defined by Anderson (2015), deductive reasoning, or deduction, is relevant to the conclusion that surely follows the assumption (p. 239). That means that the one using deduction assumes that what is true of a certain group of objects is also true about every single object from this group, i.e., reaching a logical conclusion starts with a general statement based on which the conclusion about observations is made.
- In inductive reasoning, unlike deductive, the conclusion does not necessarily follow the assumptions (Anderson, 2015, p. 251), and using induction, the general statement is reached by using observations. That means that the conclusion is made after analyzing aspects of the problem, e.g., studying symptoms to make a diagnosis. The only problem with this method is that a particular set of observations does not always lead to the same general statement. Coming back to symptoms studied to make a diagnosis, the same set of symptoms may refer to different diseases.

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- Testing and verification required observations or experiments directed on testing of hypothesis. This is similar to actions in the crime scene. With regard to the deductive criminal analysis, the modern research argues that the advantages of the deductive model of a criminal investigation are very important This model requires special education and training in the field of forensic science, the reconstruction of the crime scene, and the analysis of samples and damage in general deductive criminal record. They tend to be more specific than inductive criminal record, providing significant help in achieving the main objectives of the investigation process. Crime scene investigation constructed by inductive method begins from the observation and moves to the hypothesis which is more or less open and verifiable. During this investigation, the investigator understands what happened at the crime scene. This theory passes from the specific to the general questions. Inductive criminal investigation, according to research, is the analysis of implementation of criminal behavior, crime scenes and victims … and emotions that cause by other criminals, the crime scene and/or the victim. In fact, as the name implies, this investigation moves from the initial statistical data to identify the specific behavior of the offender. In any case, inductive criminal investigation, as a rule, based on the results of a statistical analysis. We made conclusion that both the deductive and inductive methods are required for crime scene investigation and are complementary. Perspective direction of investigation is development a special concept, which combines deductive and inductive methods of crime scene investigation.

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- Deduction and induction are both used in everyday conversations and even in scientific reasoning. Bringing together these two forms of reasoning are effective in establishing general laws, drawing conclusions about a population, predicting the occurrence of a future event-based observations of similar past events, and drawing conclusions about causes of an illness based on observations of symptoms. Thus, utilizing both of them in a debate is advisable and even ingenious.

Self-Assessment Questions

- Explain inductive reasoning
- Explain deductive reasoning
- Explain two types each of inductive and deductive reasoning
- Describe two similarities between inductive reasoning and deductive reasoning
- Differentiate between inductive and deductive reasoning
- Describe how to improve inductive reasoning
- Describe how to improve deductive reasoning

The Problem Solving Process

- Problem solving is the skill scientists use when they encounter challenges in conducting scientific investigations in order to achieve their goals. The scientists should develop the skills of identifying the problem, analyzing the problem and developing the capacity to solve the problem. Finding a suitable solution for issues can be accomplished by following the basic four-step problem-solving process and methodology outlined below:
- Define the problem
- Generate alternative solutions
- Evaluate and select the best alternative
- Implement and follow up on the solution

Define the problem

- Diagnose the situation so that your focus is on the problem, not just its symptoms.
- Helpful problem-solving techniques include using flowcharts to identify the expected steps of a process and cause-and-effect diagrams to define and analyze root causes.
- The sections below help explain key problem-solving steps.
- These steps support the involvement of interested parties, the use of factual information, comparison of expectations to reality, and a focus on root causes of a problem.
- You should begin by:

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- Reviewing and documenting how processes currently work (i.e., who does what, with what information, using what tools, communicating with what organizations and individuals, in what time frame, using what format).
- Evaluating the possible impact of new tools and revised policies in the development of your "what should be" model.
- Differentiate fact from opinion
- Specify underlying causes

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- Consult each faction involved for information
- State the problem specifically
- Identify what standard or expectation is violated
- Determine in which process the problem lies
- Avoid trying to solve the problem without data

Generate alternative solutions

- Postpone the selection of one solution until several problem-solving alternatives have been proposed.
- Considering multiple alternatives can significantly enhance the value of your ideal solution.
- Once you have decided on the "what should be" model, this target standard becomes the basis for developing a road map for investigating alternatives.
- Brainstorming and team problem-solving techniques are both useful tools in this stage of problem solving.
- Many alternative solutions to the problem should be generated before final evaluation.

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- A common mistake in problem solving is that alternatives are evaluated as they are proposed, so the first acceptable solution is chosen, even if it’s not the best fit.
- If we focus on trying to get the results we want, we miss the potential for learning something new that will allow for real improvement in the problem-solving process.
- The following steps may be useful at this stage:

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- Postpone evaluating alternatives initially
- Include all involved individuals in the generating of alternatives
- Specify alternatives consistent with organizational goals
- Specify short- and long-term alternatives
- Brainstorm on others' ideas
- Seek alternatives that may solve the problem

Evaluate and select an alternative

- A particular alternative will solve the problem without causing other unanticipated problems.
- All the individuals involved will accept the alternative.
- Implementation of the alternative is likely.
- The alternative fits within the organizational constraints.

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- Evaluate alternatives relative to a target standard
- Evaluate all alternatives without bias
- Evaluate alternatives relative to established goals
- Evaluate both proven and possible outcomes
- State the selected alternative explicitly

Implement and follow up on the solution

- Leaders may be called upon to direct others to implement the solution, "sell" the solution, or facilitate the implementation with the help of others.
- Involving others in the implementation is an effective way to gain buy-in and support and minimize resistance to subsequent changes.
- Regardless of how the solution is rolled out, feedback channels should be built into the implementation.
- This allows for continuous monitoring and testing of actual events against expectations.
- Problem solving, and the techniques used to gain clarity, are most effective if the solution remains in place and is updated to respond to future changes.

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- The following steps may be used at this stage
- Plan and implement a pilot test of the chosen alternative
- Gather feedback from all affected parties
- Seek acceptance or consensus by all those affected
- Establish ongoing measures and monitoring
- Evaluate long-term results based on final solution

Self-Assessment Questions

- Describe the problem solving process.

Scientific Ideas

- Science is all about understanding how the world works, but it's also a process.
- Science is a systematic way of observing the world and doing experiments to understand its structure and behavior.
- So, a scientific idea is an explanation for how something works, or the truth about some aspect of the world, that was figured out using the scientific process.
- Scientific ideas are usually generated when actual observations (i.e., results) match expected observations.

Sources of Scientific Ideas

- In other respects, scientific ideas are established under the influence of some factors with other ideas—affirmation, repetition, contagion, and prestige—and perhaps we may add, since we are dealing with the scientific category, reasoning; but the action of this factor is so weak that we might properly omit it.
- When it intervenes, it is chiefly to refute an accepted idea, not to establish a new one.
- The new scientific idea is rarely imposed, so far at least as the majority of minds are concerned, by demonstration.
- It must not be supposed that because a man cultivates science he is released from the yoke of established dogmas. Scientific dogmas are often the most tyrannical of all. What are the factors?

Gathering New Evidence:

- Scientific ideas are far more reliable and more likely to be true than other kinds of ideas, because they're based on evidence.
- Coming up with new scientific ideas is all about gathering that evidence.
- For example, we used to think that light was a wave.
- Then Albert Einstein and others collected evidence that light can also act like a particle.
- It turned out that light was both a wave and a particle, and it can act like both in different situations, but it was only through gathering more evidence that we were able to figure that out.

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- Scientific ideas come from evidence, but it takes brilliant thinking to imagine them.
- New ideas come from collecting evidence and looking at it to figure it out, but often it isn't as simple as it sounds.
- Some of the biggest scientific leaps in history were made by people who looked at the same evidence and drew conclusions that nobody else had thought of, but which did a better job of explaining the data.
- For example, the theory of relativity showed how Newton's laws of gravity were only a simplification, and don't work at really high speeds.
- The equations for relativity were not obvious, and so it took a lot of creative thinking to come up with.

Collaboration and Debate

- But even when you have evidence and are able to explain that evidence with clever thinking, the ideas aren't guaranteed to be accepted.
- For example, the idea that earthquakes were caused by gigantic tectonic plates moving across the surface of the earth was rejected and ridiculed.
- Only when evidence became stronger did people start to accept it.
- So how does this happen? Well, through collaboration and debate.
- People come to work together to collect new evidence, and convince each other of a new idea through their interactions.
- Scientists can be very argumentative, and have strong opinions, so debate is an extremely useful way that scientific ideas can be challenged.

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- Scientists also use a method called peer review.
- When they complete papers, presenting new ideas and evidence, those papers have to be read and critiqued by other scientists before they can be published.
- This weeds out a lot of bad quality research and builds on consensus in the community.
- When scientists are portrayed in movies and television shows, they are often ensconced in silent laboratories, alone with their bubbling test-tubes. This can make science seem isolating.
- In fact, many scientists work in busy labs or field stations, surrounded by other scientists and students. Scientists often collaborate on studies with one another, mentor less experienced scientists, and just chat about their work over coffee.

By putting Science into Practice

- Most scientists are convinced of new and changing ideas if enough evidence is provided because science is based around evidence, and so that's what scientists respond to best.
- But what about the general public? Or people who aren't research scientists themselves? How quickly the public adopts new scientific ideas can have major consequences.
- For example, climate change being caused by humans is widely accepted in the scientific community, especially among experts in the field.
- This makes it less likely that people take action to counteract the effect, and could be very damaging to the world.

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- Scientists can bring information, insights, and analytical skills to bear on matters of public concern.
- Often, they can help the public and its representatives to understand the likely causes of events (such as natural and technological disasters) and to estimate the possible effects of projected policies (such as ecological effects of various farming methods).
- Often, they can testify to what is not possible.
- In playing this advisory role, scientists are expected to be especially careful in trying to distinguish fact from interpretation, and research findings from speculation and opinion; that is, they are expected to make full use of the principles of scientific inquiry.

Nature of Scientific Ideas

- **They are Subject to Change**: Science is a process for producing knowledge. The process depends both on making careful observations of phenomena and on inventing theories for making sense out of those observations. Change in knowledge is inevitable because new observations may challenge prevailing theories. No matter how well one theory explains a set of observations, it is possible that another theory may fit just as well or better, or may fit a still wider range of observations
- **Scientific ideas are judged not by their popularity, but on the basis of the evidence supporting or contradicting them.**
- **They are not biased in nature:** Scientists do strive to be unbiased as they consider different scientific ideas, but scientists are people too.

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- **Their value can be speedily ascertained by experiment**. The most fruitful method of investigation is by imagining some hypothesis and trying to verify it, and by modifying it as new facts come to light.
- **Scientific idea can expire or die with time.** After having prevailed for a considerable length of time the idea begins to lose its hold and at last dies out. But before an old idea is wholly destroyed it has to go through a series of retrogressive transformations that require many generations for their accomplishment.
- **The scientific idea is pre-eminently established by the prestige of the man who imposes it, and rarely in any other way.**

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- **It's true that some scientific research is performed without any attention to its applications, but this is certainly not true of all science.**
- **A scientific idea may require a lot of reasoning to work out an appropriate test**, may be difficult to test, may require the development of new technological tools to test, or may require one to make independently testable assumptions to test — but to be scientific, an idea must be testable, somehow, someway.
- **In evaluating scientific ideas, evidence is the main arbiter; however, sometimes the available evidence supports several different hypotheses or theories equally well**. In those cases, science often applies other criteria to evaluate the explanations

Scientific Arguments

- Scientific argument comes from two words; scientific and argument.
- If an act is scientific then it means that the act is characterized by the methods and principles of science.
- It also means that the act is systematic and methodical.
- An argument is usually a disagreement between two or more parties where there is an exchange of diverging views.
- A scientific argument is an activity where people disagree about scientific claims and explanations using empirical data (evidence) to justify their side of the argument.

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- In this activity the opposing sides gather supporting information to build up their claims.
- The opposing sides will have to assemble ample, credible and empirical data (evidence) gathered through careful observations about the legitimacy, credibility and reliability of their claims in order to convince the other party to accept the claims.
- The claim should be backed by actual data (evidence) and logic and must be opposite to the common opinion.
- According to Popper in The Logic of Scientific Discovery an argument can only be scientific if it can be proven wrong.

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- This is known as falsifiability. In his view, science progresses by the successive rejection of falsified theories.
- For example during the rise of modern science (scientific revolution) it was generally believed that the earth was the center of the universe in the early 1500s.
- Ptolemy of Alexandria propounded that the earth is located at the centre of the universe, and all other heavenly bodies such as the sun, moon and other planets move round it in circles (Geocentric theory).
- When practically everyone believed the Earth was the centre of the universe, Polish scientist Nicolaus Copernicus (1473 – 1543) proposed that the planets rather revolved around the sun.

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- To Copernicus, the sun is at the centre of the universe while the earth and other heavenly bodies moved round it in a uniform, circular motion (Heliocentric theory).
- Galileo (1564 – 1642), an Italian, later argued that the earth revolves round the sun.
- He provided evidence to justify his claim.
- He invented a telescope and used it to view the heavens and thus confirmed the Copernican theory that the sun was at the centre of the universe.
- Therefore, the theory of geocentrism was rejected.

Communicating Scientific Arguments

- There are particular ways that a scientific argument is communicated.
- This is done through a number of means such as scientific papers, publication, poster presentations, and conference presentations.
- When you discover something, or have new evidence to present, the first step is to write a scientific paper.
- This is a document that explains the context of the work you did, how you collected data, and how you analyzed that data to reach a conclusion about what it means.
- The next step is to get it published. Scientific papers are published in journals that match the particular area of study, many of which have existed for decades or even centuries.

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- When you submit a paper, it has to go through a peer review process, which is where other scientists in the field critique your work and suggest improvements.
- If the critique goes badly enough your paper may not be published at all. Or you may be asked to rewrite certain parts of it, or address certain issues.
- Once the paper is finally published people in the scientific community are far more likely to see it, and may even cite it in their own papers.
- Last of all, you can communicate a scientific argument by giving presentations and talks.
- You might create a poster that summarizes your method and results, and stand alongside it at the conference answering questions for those who ask.

Importance of Scientific Arguments

- Scientific argumentation skills are important for students for expressing their opinions, making decisions and solving problems in daily life.
- This process can challenge wrong or unreasonable ideas, changing them into concepts that are justified by alternative interpretations of existing information and from credible evidence supporting emergent knowledge claim.
- To arrive at a common, justified conclusion, it is important to find the rationale for one's claims and use evidence to support those claims in manners befitting the work of a scientist. The creation of knowledge requires two important processes - research, upon which knowledge claims can be made, and criticisms and arguments from the community of scientists and the public, which allow those claims to be examined.
- From this analytical process, students can acquire scientific argumentation skills, filter the information received from various sources and evaluate the credibility or reasonableness of the information.

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- Scientific argumentation skills play an important part in the science classroom because each student can share their ideas on socio-scientific issues. The activities of scientific argumentation are a scientific practice based on personal construction and social mediation of knowledge.
- In particular, facing the need to argue with a close other can be energizing and motivating—the topics that bring about arguments remind us of what is important to us, from our core values to our goals for a given day.
- The use of argumentation in science education is associated helps in developing critical skills, promoting spirit of enquiry, enhancing conceptual understanding and improving academic performance of students.
- Scientific argumentation skills are important for students for expressing their opinions, making decisions and solving problems in daily life.

Determining factors of scientific argumentation

- Various factors potentially influence the student's argumentation skills.
- The quality of argumentation may be influenced by the individual's content knowledge; higher-achieving students generally have the higher content knowledge and can make broader and more complex arguments than students who have lower academic achievement levels, suggesting a link between the quality of the argument and the knowledge of the content. Likewise, argumentation quality is also shown to be influenced by the social environment, and by the teacher (Dawson & Schibeci, 2003; Sampson & Clark, 2011; Simon, Erduran, & Osborne, 2006).
- Gender affects argumentation as well – data suggests that female students are more likely to understand the details of problem situations. Females have been found to be more capable of changing their own erroneous ideas, and can generally participate and interact better with others during the discussion of concepts compared to males (Asterhan, Schwarz, & Gil, 2012; Galotti, Drebud, & Reimer, 2001; Miller, 2005; Zohar, 2006).

Cont'd

- There is also the factor of reasoning ability, which is the student's general intellectual capacity to make use of data and evidence available to support their claims (National Research Council (NRC), 2012); this is closely related to the concept of scientific argumentation skills, though the latter also implies other abilities such as the capacity to absorb additional data and change one's own false assumptions.
- The main common elements are the claims made that are supported by the warrants (reasoning) that are, in turn, based on the evidence (data). Lin and Mintzes (2010) and Toulmin (1958) have an added element to this: the backing to support the claim (supportive arguments).

Cont’d

- Furthermore, Lin and Mintzes added counter-arguments to encourage students to recognize and discuss views different from their original perspectives, and to be open to the opinions of others.
- Lin and Mintzes’ framework encourage students to both consider and refute counter-arguments.
- This process of refutation is missing in other frameworks.
- It would help us understand why some students or develop stronger arguments than others for a more effective design of the model of argument-driven inquiry instruction in the science classroom.

Cont’d

- Scientific argumentation is a dynamic, scholarly process that involves multiple elements, which encompass areas such as the ability to identify correct evidence, the mental capacity to acknowledge counter-arguments and the capability of rebutting them reasonably.
- Our data suggest that, far from being an exclusive domain of those with the strongest logical ability, the highest prior knowledge or even a predetermined gender, scientific argumentation is a distinct skill, which can be taught.
- With good approaches, students can significantly improve their ability to make proper scientific arguments. and implicit correction.

Cont’d

- Another strategy for developing argumentation skills in students might be offering them opportunities to talk to one another related to science.
- This would enable them to articulate reasons for their claim/decision to justify their stand.
- While, others will challenge their views and offer alternative answers thus improving conceptual understanding (Newton, Driver, & Osborne, 1999).
- Argumentation can also be introduced in science classrooms by facilitating students’ discourse through encouraging questions, making decisions and justifying it through reasoned argument (Polman & Pea, 2001).
- The use of evidence is very important for giving explanation and supporting one’s claim.

Self-Assessment Questions

- Explain scientific ideas
- Describe two sources of scientific ideas
- Describe the nature of scientific ideas
- Explain scientific arguments
- Describe how to communicate scientific arguments
- Describe two determining factors of scientific argumentation

THANK YOU