# CMPE 598 Seminar, on

❒ Philosophy of scientific / engineering research.

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## Scientific Method

- The scientific method is the process by which Scientists collectively and over time, effort to construct an accurate (that is, reliable, consistent and non-arbitrary) representation of the world.

## Scientist, and Scientific Method

- A **scientist** is a person who is **expert** in an area of **science** and who uses **scientific methods in research.**
- **An M.Sc candidate is expected to apply scientific methods in their thesis and studies.**



## Four steps of the scientific method:

1. **Observation and description of a phenomenon or group of phenomena.**
2. **Formulation of an hypothesis to explain the phenomena. In physics, the hypothesis often takes the form of a causal mechanism or a mathematical relation.**
3. **Use of the hypothesis to predict the existence of other phenomena, or to predict quantitatively the results of new observations.**
4. **Performance of experimental tests of the predictions by several independent experimenters and properly performed experiments.**

## The fifth step of the Scientific Method

5. The collective effort of the scientists require professional communication of the scientists. Conferences, Symposiums, Workshops, educational and post-doctoral visits are typical scientific face-to-face communication medium.

Scientific Journals, Transactions, Lecture-notes, Scientific Letters, and Proceeding notes are typical publication formats for scientist.



## Hypothesis

An hypothesis is a statement regarding cause and effect in specific situations.

it also refers to our state of knowledge before experimental work has been performed and perhaps even before new phenomena have been predicted.

Example (of Scientific Method is an Art):

"My car does not start because the battery is low."

You might actually check the voltage of the battery.

If you find that the battery is not low, you might attempt another hypothesis ("The starter is broken"; "This is really not my car.") ?

# Model

**Model is reserved for situations when it is known that the hypothesis has at least limited validity.**

**Example:**

**" The Bohr model of the atom ." where the electrons are described has moving in circular orbits around the nucleus, similar to solar system.**

**A model may explain measurements for some conditions.**



# Scientific Theory or Law

**A scientific theory or law represents an hypothesis, or a group of related hypotheses, which has been confirmed through repeated experimental tests.**

**Example:**

**" Newton's Law ." $F = m a$ .**

**"Einstein's Relativity Law." $E = m c^2$**

**"Darwin's Evolution of Species."**

**A scientific theory represents a confirmed reality by repeated experimental test. "It's only a theory." is not a good argument to oppose against a theory.**

**"Gravity is only a theory."**

**but if you step off a tall building you will definitely fall.**

## Testing of an Hypotheses

- An hypothesis is ruled out or modified if its predictions are clearly and repeatedly incompatible with experimental tests.
- No matter how elegant a theory is, its predictions must agree with experimental results. Otherwise it cannot describe the nature.

"experiment is supreme" and experimental verification of hypothetical predictions is absolutely necessary.



## Error in experiments

- Random error is error intrinsic to instruments of measurement.
- Systematic error is non-random. It is due to factors which bias the result in one direction.

No measurement, and therefore no experiment, can be perfectly precise.

It is important to determine the accuracy of a particular measurement and, when stating quantitative results, to quote the measurement error.

A measurement without a quoted error is meaningless.

The comparison between experiment and theory is made within the context of experimental errors.

# Common Mistakes

**The scientific method attempts to minimize the influence of the scientist's bias on the outcome of an experiment:**

- **Explaining a phenomenon with the hypothesis without any experimental tests does not validate the hypothesis. That is the most fundamental mistake.**
- **To ignore or rule out data which do not support the hypothesis is a common mistake. All data must be handled in the same way.**
- **The failure to estimate quantitatively systematic errors (and all errors) is an important mistake.**

**Science is a cumulative process. Scientists of different perspective and bias test the hypotheses with different measurement systems that reduce the systematic errors.**

**Over a period spanning a variety of experimental tests (usually at least several years), a consensus develops in the community as to which experimental results have stood the test of time.**



# Are there circumstances in which the Scientific Method is not applicable?

**Scientific method is applicable in most everyday problems, i.e., to fix a broken phone line**

**"Is the phone signal coming from the line?" or**

**"is the handset wire broken?"**

**You can test each of these hypotheses, and get closer to the solution.**

- **Freud says that "Human behavior is not rational". Scientific method may not work in human relations.**
- **Some disciplines are based on rational, but changing the measurement conditions are impossible, in such cases the results may depend in part on the history of a situation (Pseudo-science cases).**
- **This often occurs in social interactions between people.**

**For example, arguments of a lawyer may influence a jury in court, but may not influence next time for a very similar case in a new trial because the jury composition will be different.**

# The Method of Science

**Donald E. Simanek**

**The "scientific method“ presented in schools and textbooks as a "recipe" for doing science, with numbered steps are misleading.**

**Here's some informal comments about scientific method presented as a set of practical and general guidelines for doing science.**

**Scientists have learned these through trial and error during the entire history of science.**



# The Methods of Science

- **Extrapolate a model. If extrapolation fails you need another model.**
- **Test a model with more precise measurements, If the model fails you need patches to the model, or another model.**

**This is called a revolution of the theory**

**Newton’s Law fails to explain the force-acceleration relation if the speed of mass is comparable to the speed of light. Thereafter the relativity theory explains the observations.**

**Quantum Mechanics, Fuzzy Set Theory, are examples of scientific revolution of the theory**

## The Methods of Science

- The history of science has been a process of finding successful descriptive models of nature.
- Whatever models or theories we use, they usually include some non-measurable and non-observable details or virtual concepts .
- So scientists often speak of virtual concepts such as energy, momentum, wave functions and force fields as if they were on the same status as objects of everyday experience such as rocks, trees and water.

A change of scientific model may sweep away the concept of force field.



## The Methods of Science

The notion to find absolute and final truths is naive.

- A model may work within its frame, and may need modification in another frame.
- A need of modification does not make the old model "untrue"

Science limits itself to more finite questions for which we *can* arrive at practical answers.

## The Methods of Science

- Any question that is in principle or in practice untestable, is not considered a valid scientific question.

"What is the meaning of it all,"

"What lies outside the universe," or

"What jump-started the universe?"

These are the concerns of the Philosophers, not the Scientist.



## The Methods of Science

- Science progresses through trial and error, mostly error. Every new theory or law must be skeptically and rigorously tested before acceptance.
- Others, like the “luminiferous ether,” flourish for a while, then their inadequacies accumulate till they are intolerable, and they are abandoned when something better comes along.

# The Methods of Science

**CONCLUSION**

- **Science progresses by making mistakes, correcting the mistakes, then moving on to other matters. If we stop making mistakes, scientific progress would stop.**



# The SM-14 Formula - MAJOR STAGES -I

**Norman W. Edward (edward scientific instruments inc.)**

**The SM-14 Formula for the General Pattern of the Scientific Method**

**PART I - Observation through Hypothesis**

- **1. Curious Observation**
- **2. Is There a Problem?**
- **3. Goals and Planning**
- **4. Search, Explore, and collect the Evidence**
- **5. Generate Creative and Logical Alternatives**
- **6. Evaluate the Evidence**
- **7. Make the Educated Guess (Hypothesis)**

## The SM-14 Formula MAJOR STAGES -II

**PART II - Challenge through Suspend Judgment**

- **8. Challenge the Hypothesis**
- **9. Reach a Conclusion**
- **10. Suspend Judgment**



## The SM-14 Formula MAJOR STAGES -III

**PART III - Implementation, Peer Review**

- **11. Take Action**

**Action includes observations, measurements, and publications of the method and results.**

## The SM-14 Formula SUPPORTING INGREDIENTS

**SUPPORTING INGREDIENTS**

- **12. Creative, Non-Logical, Logical, and Technical Methods**
- **13. Procedural Principles and Theories**
- **14. Attributes and Thinking Skills**

**Norman W. Edward (edward scientific instruments inc.)**
**http://www.scientificmethod.com/index.html**



# TEN MYTHS OF SCIENCE:

**REEXAMINING WHAT WE THINK WE KNOW...**

**W. McComas 1996**

# TEN MYTHS OF SCIENCE:

- **Myth 1: Hypotheses Become Theories Which Become Laws**

**Some hypotheses are valid even if they are not directly testable, i.e., Darwin's "evolution of species" because they explain all observations in best and simplest manner.**

**Newton described the relationship of mass and distance to gravitational attraction between objects with such precision that we can use the law of gravity to plan space flights. They are valid and useful even after the Einstein's relativity theory.**

**Usefulness in practice is the key for the validity.**



# TEN MYTHS OF SCIENCE:

- **Myth 2: A Hypothesis is an Educated Guess**

**Most theories contain some sort of virtual concepts to explain the observations. That virtual concept makes them "theory", i.e. Fuzzy Set Theory, Relativity Theory, etc.**

**A statement that directly explains the observations is called a law, i.e., Newton's law, Ohm's law**

**A hypothesis started as an educated guess can never be a theory, or law, even after verification by all available observations.**

**When students are asked to propose a hypothesis during a laboratory experience, the result is scientific prediction rather than hypothesis.**

# TEN MYTHS OF SCIENCE:

- **Myth 3: A General and Universal Scientific Method Exists**

**Statistician Karl Pearson (1937) introduced for the pre-college textbooks the ingredients of the scientific method as**
**a) define the problem, b) gather background information,**
**c) form a hypothesis, d) make observations,**
**e) test the hypothesis, f) draw conclusions,**
**and in some texts g) communication of results.**

However, **there is no single method in science**. Instead, several methods, including **many discoveries by chance** is a typical pattern.

**The scientists approach and solve problems with imagination, creativity, prior knowledge and perseverance.**



# TEN MYTHS OF SCIENCE:

- **Myth 4: Evidence Accumulated Carefully Will Result in Sure Knowledge**

**In his book Novum Organum Frances Bacon (1620/ 1952) formulized induction.**

**The method of induction he suggested is the principal way in which humans traditionally have produced generalizations that permit predictions. What then is the problem with induction?**

**Scientists formulate laws and theories that are supposed to hold true in all places and for all time but the problem of induction makes such a guarantee impossible.**

# TEN MYTHS OF SCIENCE:

- **Myth 5: Science and its Methods Provide Absolute Proof**

**Accumulated evidence can provide support, validation and substantiation for a law or theory, but will never prove those laws and theories to be true [Homer and Rubba (1978) and Lopnshinsky (1993)].**

**In practice, the only truly conclusive knowledge produced by science results when a notion is falsified.**

**What this means is that no matter what scientific idea is considered, once evidence begins to accumulate, at least we know that the notion is untrue.**



# TEN MYTHS OF SCIENCE:

- **Myth 6: Science Is Procedural More Than Creative**

**We accept that there is no single guaranteed method of science.**

**But, induction, the collection and interpretation of individual facts providing the raw materials for laws and theories, is at the foundation of most scientific efforts.**

**Creativity is a major component of all scientific methods. If procedures were determining the theories, there would be no different perspectives and no creative ideas, which are subject of scientific testing methods.**

# TEN MYTHS OF SCIENCE:

- **Myth 7: Science and its Methods Can Answer All Questions.**

**Philosophers of science have found it useful to refer to the work of Karl Popper (1968) and his principle of falsifiability to provide an operational definition of science. Popper believed that only those ideas that are potentially falsifiable are scientific ideas.**

**For instance, the law of gravity states that objects with a large mass exert a stronger gravitational attraction than do objects with less mass when distance is held constant. This is a scientific law because it could be falsified if newly-discovered objects behave differently.**

**Science simply cannot address moral, ethical, aesthetic, social and metaphysical questions.**



# TEN MYTHS OF SCIENCE:

- **Myth 8. Scientists are Particularly Objective**

**Many philosophers of science support Popper's (1963) view that science can advance only through a string of what he called conjectures and refutations.**

**In other words, scientists should propose laws and theories as conjectures and then actively work to disprove or refute those ideas. Related to the issue of theory-based observations is the allegiance to the paradigm. Thomas Kuhn (1970), in his ground-breaking analysis of the history of science, shows that scientists work within a research tradition called a paradigm.**

**When research reports are submitted for publication they are reviewed by other members of the discipline. Ideas from outside the paradigm are liable to be eliminated from consideration as crackpot or poor science and thus do not appear in print.**

# TEN MYTHS OF SCIENCE:

## ■ Myth 9: Experiments are the Principle Route to Scientific Knowledge

**Throughout their school science careers, students are encouraged to associate science with experimentation. Virtually all hands-on experiences that students have in science class is not experiment, but some kind of technical exercises, technical procedures, explorations or activities.**

**Charles Darwin used observation notes rather than experiments, as usual in social sciences. Although Darwin supported the inductive method proposed by Bacon, he was aware that observation without speculation or prior understanding was both ineffective and impossible. The techniques advanced by Darwin have been widely used by scientists Goodall and Nossey in their primate studies.**

**Scientific knowledge is gained in a variety of ways including observation, analysis, speculation, library investigation and experimentation.**



# TEN MYTHS OF SCIENCE:

## ■ Myth 10: All Work in Science is Reviewed to Keep the Process Honest.

**In reality, Most scientists are simply too busy and research funds too limited for the verification and review studies.**

**The lack of verification has recently put science itself under suspicion. With the pressures of academic tenure, personal competition and funding, instances of fraud is expected.**

**Even without fraud, the enormous amount of original scientific research published, and the pressure to produce new information rather than reproduce others' work dramatically increases the chance that errors will go unnoticed.**

**An interesting corollary to this myth is that scientists rarely report valid, but negative results. While this is understandable given the space limitations in scientific journals, the failure to report what did not work is a problem.**

**Only when those working in a particular scientific discipline have access to all of the information regarding a phenomenon -- both positive and negative -- can the discipline progress.**

# TEN MYTHS OF SCIENCE:

- **Conclusions**

**There is no single scientific method in science.** There are methods of science with some elements parallel to the scientific method characterized in the textbooks.

**A new hypothesis, model, or theory requires creativity and speculations rather than analysis of the observation and experimental results.**

**Science has a scope limited by the falsifiable hypotheses. It cannot answer all questions, i.e., ethical and religious.**

**Scientific knowledge is gained in a variety of ways including observation, analysis, speculation, library investigation and experimentation**



# TEN MYTHS OF SCIENCE:

- **References**

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## Place and importance of M.Sc Thesis

Place and importance of M.Sc Thesis in
- scientific,
- social,
- local, and
- personal development



## Place and importance of M.Sc Thesis Scientific Importance

- An M.Sc Thesis can be on implementation of technical concepts, measurements or observation of systems, or development of novel methods and systems to solve some practical problems.
- M.Sc Theses are an important source of scientific experimental measurements, and observations.
- They may introduce new ideas and models to the academic world.
- A M.Sc. dissertation must be in a scientific publication format that is suitable for scientific communication.

## Place and importance of M.Sc Thesis

### Social Importance:

**Social issues and problems form typical M.Sc. Theses subjects.**

**Society profits from the expertise of the graduate, by the technical and professional guidance of the graduate.**

An M.Sc thesis subject shall never be in conflict with the benefits of the society.



## Place and importance of M.Sc Thesis

### Local Importance:

**Generally, the problems of the local industry and community are preferred for the M.Sc. Thesis subjects.**

## Place and importance of M.Sc Thesis on Personal Development:

An MSc Thesis gives to the graduate an opportunity to be specialized on a particular topic through scientific and experimental studies.

By presenting scientific publications the graduates meet the frontiers and authorities of their field of study.