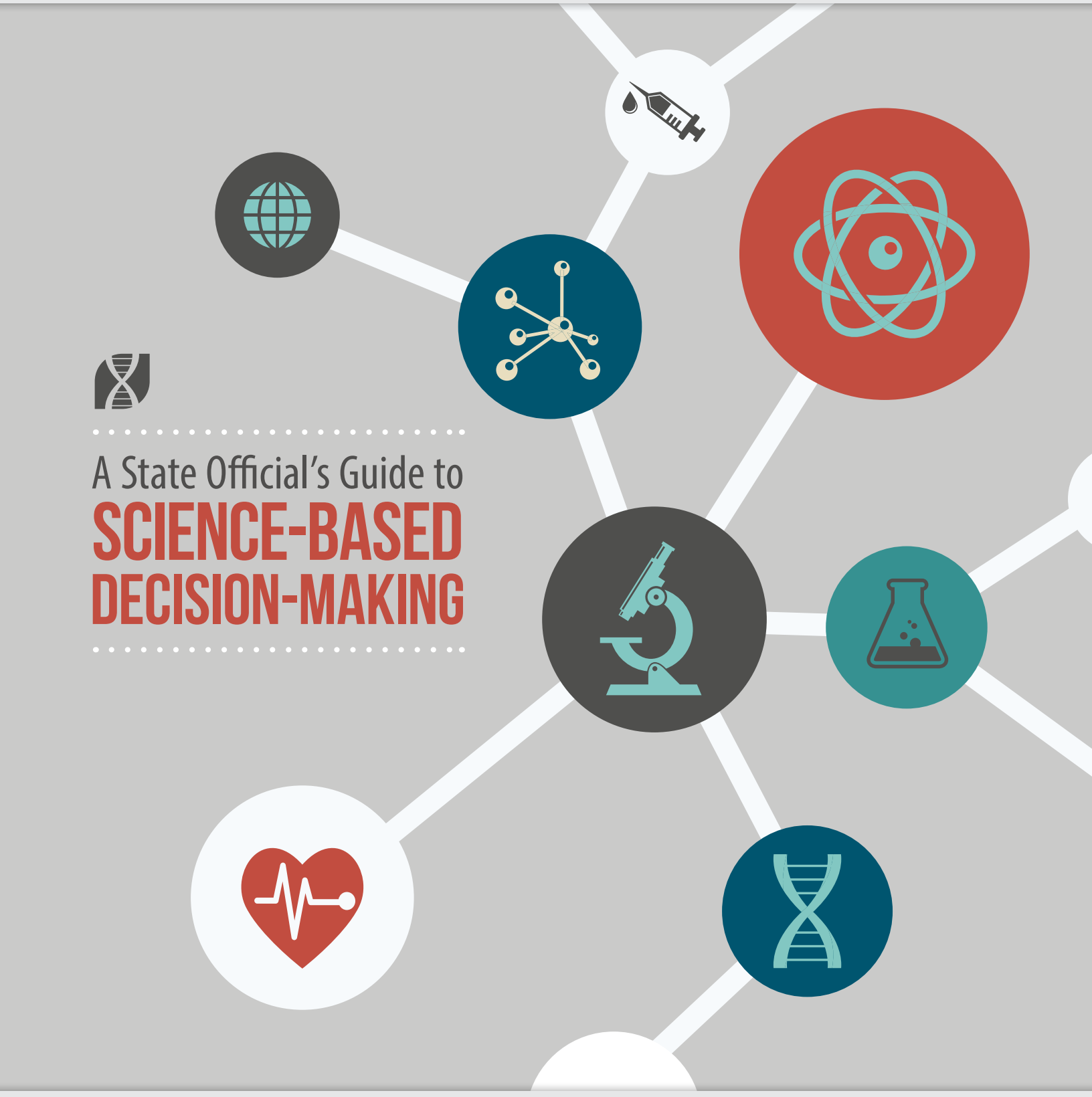

A State Official's Guide to SCIENCE-BASED DECISION-MAKING

The Council of State Governments
Sharing capitol ideas.

ACKNOWLEDGMENTS

The Council of State Governments would like to express appreciation to the Sound Science Advisory Board for lending its expertise to this project and reviewing drafts of the report. Advisory board members include:

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- Dr. Steve Cohen, Executive Director, The Earth Institute, Columbia University
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This report refers to several examples of state and federal policies that are based on scientific information. These examples were chosen solely for their relevance to the concepts explained in the text. Neither CSG nor the Sound Science Advisory Board advocate these policies.

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Policymakers are bombarded by information in today's ever-connected, fast-paced world. Advances in communication platforms, like social media, and information technology have brought a sea change in the public's ability to access data at unimaginable depths and speeds. This interconnectedness can also pose challenges for state officials trying to solve already difficult issues by adding another layer of complexity to the public policymaking process. As information becomes more available and immediate, policymakers often must make decisions without the technical background necessary to fully vet all the considerations involved.

The Council of State Governments developed A State Official's Guide to Science-based Decision-making to provide strategic guidance that can cut through the jargon and spin that can accompany technical issues. The guide includes recommendations and helpful tools for policymakers, regardless of background, to confidently assess the assumptions, conclusions and results found in state public hearing witness testimony and scientific studies.

"The aim of the guide is not to suggest what to think; rather, the impetus is to provide a roadmap of how to approach an issue so state thought leaders can make the most informed decision possible."

Assessing the Expert

Nearly all public meetings or hearings on technical issues will feature expert witness testimony or studies of some kind. State officials must be able to distinguish advocacy from expertise and recognize when witness statements or testimony ventures into areas of personal opinion, anecdote or conjecture. Advocacy has an important place in the public policymaking process, but its primary goal is to influence or promote a cause rather than provide unbiased information.

Questions to Ask and Warning Signs:

- **What educational background or training does the expert have?**
- **What types of work has the expert done in the field?**
- **Does the source of the research have anything to gain by the study's outcome? Are there conflicts of interest either financially or professionally?**
- **Is the expert or the expert's employer concerned about implications of a policy/decision?**
- **Be on guard for an observer's bias or potential vested interest.**

Assessing the Methods

Data can be derived from many sources, including case studies, observational studies, controlled studies and risk assessments. This process analyzes how the data collection was performed or how information was gathered, which underpins a study or set of results. Many studies make calculated assumptions and can involve intricate variables. How those variables are controlled can have a tremendous impact on the final results, which can form the basis of an economic impact analysis, policy decision or regulatory action, etc.

Questions to Ask and Warning Signs:

- **Who gathered this information?**
- **What specific data or studies form the basis of the researcher's scientific conclusions?**
- **Have the data or studies been evaluated by other scientists? How extensive was the review?**
- **Have important variables been overlooked or ignored?**
- **Is the sample size used in the study truly representative?**
- **What specific hypotheses or questions did the researchers set out to test? Were steps taken to control other effects?**
- **Watch for studies that lack accepted standards or credible references.**

Assessing the Results

Once data are produced, a policymaker must then be able to make sense of its outcome and relevancy. One common mistake is a confusion of correlation, which is an apparent connection between variables when they frequently occur together, with causation, in essence, a statement of cause begetting an effect. Further, a general understanding of the statistical significance of the results in a study is paramount. Statistical significance is a technique that calculates the probability that an effect observed in a research study is occurring because of chance.

Questions to Ask and Warning Signs:

- **What are the underlying systematic uncertainties? What degree of uncertainty surrounds the results?**
- **Were conclusions based on personal stories/anecdotal evidence?**
- **Do the results demonstrate causality, rather than correlation?**
- **Are the results statistically significant?**
- **Are statistics adequately explained? If not, ask for a practical explanation.**
- **To whom or for what do the results apply? Can they be extrapolated to the general population?**
- **Do the conclusions logically follow from the scientific results?**
- **Be on guard for conclusions making statements of absolute certainty.**

Integrating the Knowledge

This segment focuses on critically assessing and formulating the disparate data points and facts learned or gleaned from testimony, study methodologies and results to help inform the actual decision-making process. This segment will address the role of risk assessments in integrating knowledge and helping policymakers in their decision-making.

Questions to Ask:

- **Have the study results been published? If yes, was it in a journal that requires peer review prior to publication? Have any scientific peer review panels considered the study results?**
- **Is there a consensus about the key findings of the studies? What are the areas of agreement/disagreement?**
- **Do other scientists share the researcher's views? Who doesn't and why?**
- **Have the results been repeated, confirmed or supported by other studies?**
- **What are your views on the practical applications of this scientific knowledge/decision?**
- **Is the timeliness of study relevant to today's issues?**
- **What are the consequences/implications of action or inaction, including risks? Is there a balanced approach? Why or why not?**

Conclusion

Science informs just one part, albeit a critically important one, of the policymaking process; it is not a policy itself. Sometimes there simply is no clear-cut answer science can provide to determine consensus. Policymakers must be able to distinguish advocacy from expertise, understand how scientific data were gathered, be willing to assess the process to gather the data and recognize the relevancy of the data to present-day topics. After policymakers learn and assess data and facts, they must then utilize risk assessment to make decisions. Ultimately, the choices made in resolving complex technical issues reside in a leader's ability to ask straightforward questions about the data and distinguish facts from advocacy—no easy task in today's hypercharged political environment. This guide strives to help make that process less daunting and facilitate better outcomes that could be applied across a host of policy discussions.

INTRODUCTION

State officials face tremendous challenges and opportunities when making policy decisions in the Internet age. Officials and their constituents have instant access to huge amounts of information and scientific knowledge. This nearly inexhaustible wealth of information can provide state officials with valuable resources for making informed decisions. On any given issue, they can review reams of data, read numerous studies and consult an endless parade of experts. A greater understanding of health, environmental, economic and social issues empowers state officials to enhance their constituents' quality of life as never before. Consider this: according to Peter Diamandis and Steven Kotler's book Abundance, a Masai warrior in sub-Saharan Africa has access to more computing power through a smartphone than was available to the president of the United States in 1997.

This flood of information, however, further complicates addressing policy issues. Inundated with scientific studies, expert opinions and attention-grabbing headlines, policymakers may have more information than they possibly can assimilate. But that quantity of information is compounded by uncertain utility—just because the information exists does not mean it is accurate or relevant. Policymakers also should keep in mind that science does not always have the answers to policy questions.

Distinguishing quality information from the bad and useful information from the irrelevant has never been more challenging than with the rise of Internet publishing and its effects on the policy process. After all, state officials cannot dismiss the immense contributions of science to public policy. At the same time, they must be wary of misallocating public resources based on misleading scientific claims. Officials need to know how to recognize credible and pertinent scientific studies, which questions to ask of scientific experts and how to integrate scientific information into their policy decisions. Therefore, The Council of State Governments has developed A State Official's Guide to Science-based Decision-making as a high-level reference tool to assist in separating the wheat from the chaff.

Science-based Decision-making—Its Intent

Uncertainty is an inherent part of science-based decision-making, and state officials should be prepared to look past the attention-grabbing headline and dig deeper to question claims or studies that do not document potential variables. The goal of this document is to help improve that decision-making process by removing clutter and offering a path toward clarity.

State officials do not have the capability to sort scientific research presented to them into two bins labeled "Useful in Decision-making" and "Junk: Discard." Instead, science comes in varying levels of quality and usefulness.

> **"The scientific community views research as more credible when it clearly states the problem being tested, follows established procedures for collecting and analyzing data, and is reviewed by other scientists."**

The scientific community views research as more credible when it clearly states the problem being tested, follows established procedures for collecting and analyzing data, and is reviewed by other scientists. Studies that deviate from one or more of these criteria, however, may provide state officials with useful information, such as identifying potential risks to public or environmental health that should be monitored as they develop. Before dismissing such claims or studies, state officials should review them with closer scrutiny.

Science cannot explain our world with 100 percent certainty. Basic mathematic principles uphold fundamental pillars of quantitative natural sciences like chemistry and physics. But no scientific study can guarantee that it accounted for all factors at work, nor can its results, based on a limited sample, be generalized to an entire population in all cases. Accepted beliefs are discarded when new evidence is collected through additional studies and with improved research tools. Persistence is as necessary and valuable today as it was when Copernicus startled the medieval world by theorizing the Earth was not the center of the universe. Credible scientists and organizations are careful to explain sources of uncertainty in their findings, studies and testimony.

Contested Science

Everyone agrees public policy should be based on the best available scientific and technical information. But it is not uncommon for experts and others to have different interpretations of facts. These differences seem to emerge for one or more of the following reasons.

Lack of Information

Although the amount of data and information has grown in recent decades, along with access to such information, it is rare to face a policy problem where the information lights the way to an obvious solution. Often parties do not have the information they need because there is not enough data; there's too much data to absorb; the data that do exist are outdated; access to certain data may be restricted; the data are inconclusive or isn't relevant to the decision at hand; existing studies have different objectives, assumptions, or methods of data collection and analysis; and data exist but has not been analyzed sufficiently to provide useful information.

Lack of Agreement

Decision-makers, experts and advocates also may disagree on what information is needed to inform a particular decision. Participants in the policy process may define the problem and objectives differently, which thereby leads them to different conclusions about what information is needed. They also may disagree on procedures for assessing data and how to interpret data.

Lack of Incentives

The process of formulating and implementing public policy is characterized by an adversarial environment that often pits science against politics and one interest group against another. Advocates seek to prevail rather than to resolve their differences effectively. Each side seeks to gain an advantage by exploiting existing scientific and technical uncertainty. Incomplete understanding is used to delay decisions opposed by one group or individual. Scientists with different interpretations of the same data are pitted against each other, thereby canceling out what they have to say. The use of science in an adversarial way undermines trust in science, experts and the decision-making process.

Lack of Capacity

In some situations, some stakeholders have access to the data and others do not, either because the information is confidential or because parties have unequal scientific and technical resources. It is also not uncommon for some stakeholders to have more expertise and a better understanding of the data than others. Finally, different participants are likely to have different tolerances for risk and uncertainty.

Lack of Communication

Disputes over scientific and technical information also may emerge because of a lack of communication and understanding among experts, decision-makers and advocates. This lack of communication is fostered when issues of interest to scientists are not those of most interest to decision-makers and stakeholders; the decision-making process is on a shorter timetable than is the science; scientists' values influence the questions they are asking; or the participants have unrealistic expectations of the experts, science and ability to predict the future.

Media Hyperbole or Oversimplification

Bad news sells, and some members of the media may highlight minimal disagreements or cite antagonists that make the issue look out of proportion. In addition, many writers do not have a technical background and may lose important details or nuance when summarizing a story or gathering information on a debate. State policymakers must look beyond the headline of a news story before drawing conclusions.

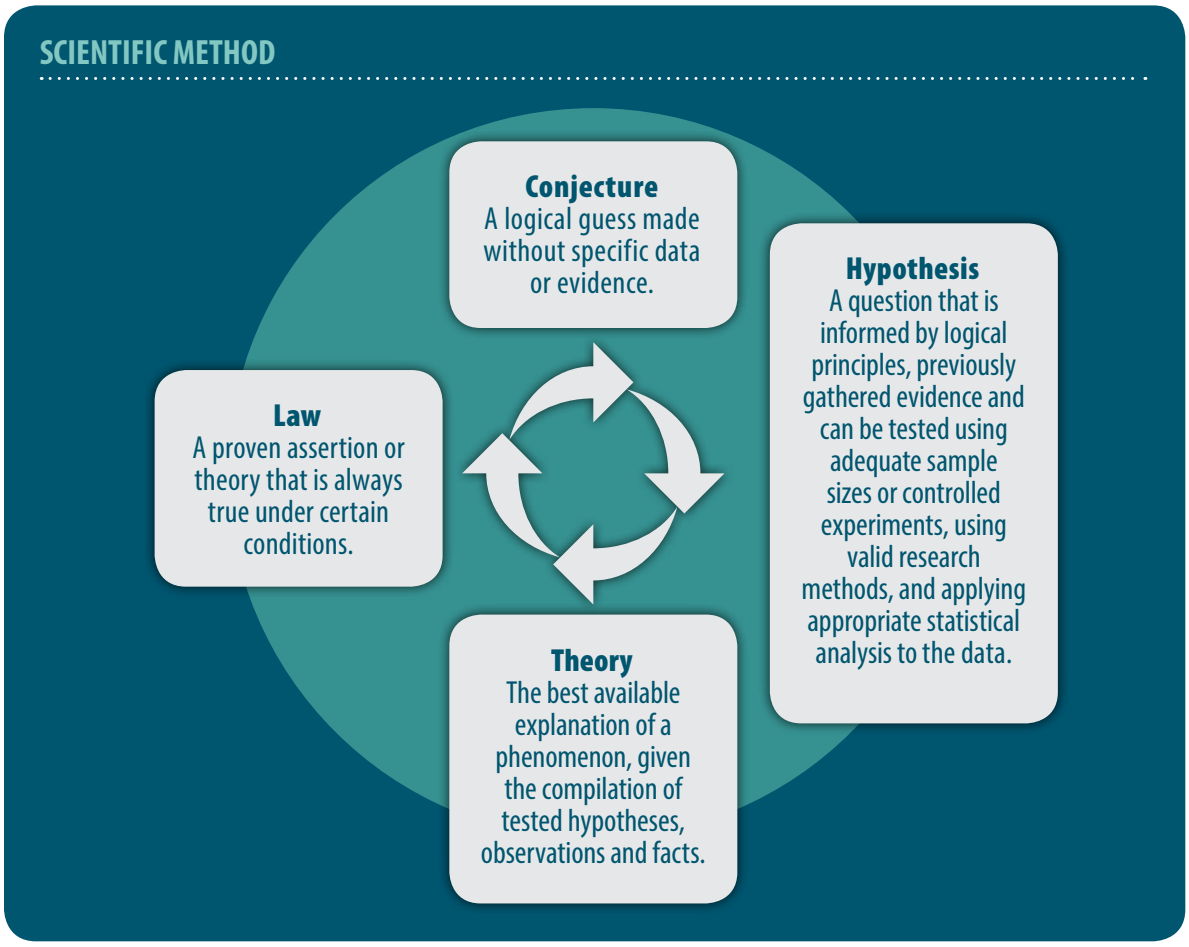
THE SCIENTIFIC METHOD

Quality science can be described as research conducted by trained individuals using documented methodologies that lead to verifiable results and conclusions. The scientific method, as illustrated on Page 9, is the conventional model of a research process that meets these criteria. Though not all scientific studies follow each step in this model, the scientific method is a convenient benchmark for state officials to use when evaluating scientific studies. The principles of the scientific method can essentially be broken into four aspects:

» Conjecture – a logical guess made without specific data or evidence;
» Hypothesis – a question that is informed by logical principles, previously gathered evidence and can be tested using adequate sample sizes or controlled experiments, using valid research methods, and applying appropriate statistical analysis to the data;
» Theory – the best available explanation of a phenomenon, given the compilation of tested hypotheses, observations and facts; and
» Law – a proven assertion or theory that is always true under certain conditions.

The scientific community develops theories from the accumulation of research findings. Commonly accepted theories can change as scientific knowledge evolves, demonstrating the inherent uncertainty of science. Because other variables could be tested and more subjects or research trials could be studied, no experiment can produce results that are 100 percent certain. Science is inherently dynamic. Scientific theories can on occasion become scientific laws, but the process for doing so is quite difficult and can take decades. Scientific laws are most often found in the natural sciences like chemistry and physics which involve mathematic equations. However, it's important to remember that scientific questioning led a technical assistant in the Swiss Patent Office named Albert Einstein to question Newton's laws of mechanics when he developed his General Theory of Relativity.

"Quality science can be described as research conducted by trained individuals using documented methodologies that lead to verifiable results and conclusions."



METHOD	DESCRIPTION	ADVANTAGES	DISADVANTAGES	COMMON APPLICATIONS
Case studies	An in-depth analysis, often through observation, of one or several individual examples in hopes of generalizing the results to a larger population.	Provides extensive knowledge of particular cases; can help in problem recognition and hypothesis formulation.	Cannot be certain the example is representative of the entire population.	Background information; hypothesis formulation; identification of emerging problems.
Clinical trials	A carefully designed investigation of the effects of a drug, medical treatment or device on a group of human subjects as cases and controls.	Allows researchers to ensure the safety of medical treatments before they are made accessible to the general public.	Treatment may have unexpected side effects on test patients; control subjects may be denied a beneficial treatment.	Medical studies of pharmaceutical or surgical efficacy (often associated with the Food and Drug Administration)
Epidemiological studies	An attempt to measure the frequency and severity of disease in populations, identify harmful environmental effects, and establish the safety and effectiveness of drugs, surgery and other forms of medical treatment.	Suggests a relationship between two factors or events; best at identifying powerful associations but may produce contradictory results with weaker relationships.	Cannot establish cause and effect.	Health reports; establishing possible risks or factors to target for prevention programs.
Field or observational study	An experiment conducted in a natural setting, often when investigating cause-and-effect relationships that cannot be brought into a controlled setting. Sometimes used in combination with scientific computer modeling. *	Relies on observation of real-life situations, rather than a laboratory construct.	May be difficult to replicate; does not permit the level of control or confidence of a laboratory-based experiment; difficult to establish causation.	Environmental impact research; behavioral studies.
Laboratory experimentation	The study of a proposed cause-and-effect relationship in a highly controlled setting. Often involves the use of a treatment group and control group.*	Controlled experimental setting maximizes accuracy of cause-and-effect findings.	Laboratory setting may be too artificial to produce realistic results, making generalizations from the findings difficult.	Elaboration on observations that have been made in people; test for possible hazards or benefits of substances or circumstances.
Meta-analysis	A statistical analysis of multiple studies of recent research on a particular topic or phenomenon. Provides a means to increase the statistical power of small numbers of observations by pooling data from two or more studies.	May be more efficient than setting up and conducting an experiment; provides thorough assessment of prior research.	Does not provide original research on an issue; pooling data from multiple studies conducted by different researchers with different subjects may not be valid.	Evaluating the statistical strength of the conclusions from a collection of scientific studies.
Surveys	A method of collecting information directly from people, usually in the form of a questionnaire or interview, analyzing the responses, and inferring how the findings relate to a larger group of individuals.	Allows for direct response from human subjects.	Sampling may not be representative of the population under study; responses rely on recall and truthfulness, either of which factors may lessen the accuracy of survey responses.	Social scientific research, such as cultural issues and marketing studies; health studies.
Scientific (computer) modeling	A simulated representation of a real-world process based on an assembly of knowledge gained from a wide array of observations. Models are tested under varied conditions in order to assess their reliability.	Used to understand what has caused various changes, to test different control strategies and to develop predictions; enables researches to answer the question "What if…?" or to examine the possible consequences of certain actions before harm is caused.	A model cannot prove a theory, only demonstrate the implications of what is already known about a process; limited by what is currently known about causal variables; unknowns must be fixed by assumptions or left out of model.	Climate and weather; environmental impacts; animal behavior.

*Source: *Interpreting Communication Research.* Carl H. Botan, Lawrence R. Frey, Paul G. Friedman and Gary L. Kreps. Englewood Cliffs, 1992.

As a general guide, the scientific method outlines recognizable characteristics of quality studies: a credible source, sound methodology, careful statements of association or causality, clear measures of confidence, some degree of peer review or evaluation by fellow practioners, and the publication in a scientific journal where findings can be evaluated by outside sources to determine veracity. State officials can refer to these characteristics when looking for warning signs that a study may be faulty, which should lead them to question the study more critically.

The Scientific Method Applied

Note to reader: Starting below and throughout the Guide to Science-based Decision-making, a fictional character named Mr. Greenthumb will be used as an illustrative example of the technical concepts discussed.

An example of the scientific method at work might begin with a plant shop owner noticing that his plants are less healthy than those of a nearby store owner who talks to her plants each day. To figure out why the other nursery's plants are larger than his own, Mr. Greenthumb proposes the hypothesis: "Talking to your plants for 15 minutes a day will cause them to grow faster."

Mr. Greenthumb then develops a methodology to test this hypothesis. He gathers an experimental group of 30 plants of the same type and same height. He plans to treat 15 plants in Room A—the treatment group—to daily conversation and to avoid any speech while tending to the 15 plants in Room B—the control group. The control group will test whether a single variable—daily conversation—is responsible for an observed effect—increased plant growth. To conclude that any variation in height between the groups of plants is the result of conversation, Mr. Greenthumb must keep all other variables—such as sunlight, temperature and watering amounts—the same in both rooms.

Mr. Greenthumb then performs the experiment and collects data. For one month, he talks animatedly to each of the plants in Room A for 15 minutes each day, and he remains silent while in Room B. Before, during and after this experiment, he measures and records the height of all 30 plants.

Once the experiment is complete, Mr. Greenthumb's data analysis and interpretation of the plant measurements show what happened during the month of disparate treatments. Suppose the data analysis shows the plants in Room A grew faster than those in Room B. He uses statistical analysis to determine if the variation in growth between the two groups falls within the normal range for these plants. Because the growth rate is greater than would be expected in the typical plant population, Mr. Greenthumb concludes the results support his original hypothesis—talking to the plants did increase their growth rate.

In light of these findings, Mr. Greenthumb sends a report of the study to a scientific journal. Before publishing the report, the journal editors send it to several botanists to conduct a peer review of the study's methodology and conclusions. They scrutinize the study for consistent, logical arguments and for reasonable findings based on the data presented. Based on the peer review, the editors may recommend Mr. Greenthumb collect more data or revise the report. Once the editors are convinced Mr. Greenthumb's study is sound, the journal publishes the report to be reviewed by the scientific community. This may lead to replication or extension of Mr. Greenthumb's research as other scientists try to confirm his results or to expand them in new testable hypotheses.

Common Research Techniques

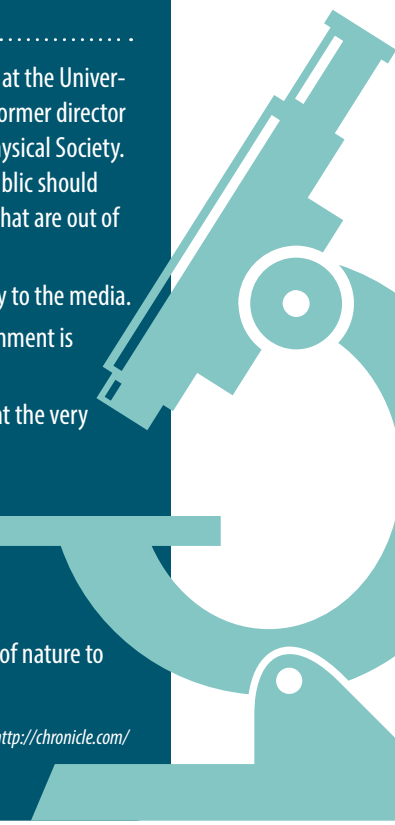
Scientists can use several common research techniques during the experimentation phase. Researchers tend to rely on the methods that best suit their subject area. For instance, medical researchers favor clinical trials to determine the effectiveness and possible side effects of new medications. While these studies are not the best for evaluating causation, environmental scientists frequently use field or observational studies to evaluate subjects or events in

Seven Signs of Bogus Science

Dr. Robert L. Park is a professor of physics at the University of Maryland at College Park and the former director of public information for the American Physical Society. He developed seven warning signs the public should consider as indicators of scientific claims that are out of bounds of rational scientific discourse.

1. The discoverer pitches the claim directly to the media.
2. The discoverer says a powerful establishment is trying to suppress his or her work.
3. The scientific effect involved is always at the very limit of detection.
4. Evidence for a discovery is anecdotal.
5. The discoverer says a belief is credible because it has endured for centuries.
6. The discoverer has worked in isolation.
7. The discoverer must propose new laws of nature to explain an observation.

Source: *The Chronicle of Higher Education*. Jan. 31, 2003. *http://chronicle.com/article/The-Seven-Warning-Signs-of/13674*



nature. And social scientists typically collect data through case studies or surveys.

State officials should be familiar with the variety of research techniques to recognize if a particular study uses an approach appropriate to the subject matter, if the researcher performs the technique correctly, and if the study's conclusions logically follow from that technique. The chart on Page 10 highlights a few of the most common research techniques, lists their advantages and disadvantages as tools of scientific study, and describes some of their most common applications.

Research can be categorized into two types—basic and applied. Basic research involves theoretical or experimental investigation to advance scientific knowledge without an immediate practical application as a direct objective. Colleges and universities typically perform basic research with government funding. Applied research uses knowledge gained through theoretical or experimental investigation to make things or create situations that will serve a practical purpose. Typically, private companies or nonprofit organizations that are trying to solve a particular problem perform applied research. State officials can turn to basic

A Cautionary Tale: Autism and Vaccines

Few recent examples in public health provide a more compelling example of the impacts bogus science can have than the debunked claim that some components used in vaccines can lead to increased rates of autism in young children. Autism spectrum disorders occur in an estimated 1 in 68 children in the U.S. based on a 2014 survey by the Centers for Disease Control and Prevention. In the mid to late 1990s, increased rates of autism diagnoses in children led researchers to suggest a relationship to a yet undetermined causal link. Some suggested a common preservative called thimerosal found in many vaccines contributed to the uptick in rates of autism.

The well-respected British medical journal Lancet in 1998 published a prominent study by Dr. Andrew Wakefield. The study claimed that combining a shot for the measles, mumps and rubella—known as MMR—into one vaccine caused weakening in the immune and digestive systems of children and led to increased occurrences of autism. His study claimed a dozen "previously normal" children developed gastrointestinal problems and developmental disorders, including autism. Wakefield's study concluded, "in most cases, onset of symptoms was after measles, mumps, and rubella immunization. Further investigations are needed to examine this syndrome and its possible relation to this vaccine."

The Wakefield paper set off a public health scare in the United Kingdom and in the U.S., with parents worried the immunizations given to their children at young ages would potentially cause developmental issues associated with autism. The Wakefield study had one major flaw—it wasn't true. Critics pointed out the information was incomplete and was based on a small set of cases with no controls, linked three common conditions and relied on parental recall and their suppositions. Investigative journalist Brian Deer found that Wakefield altered numerous parts of the children's medical history to help corroborate his findings of a new syndrome. Deer also reported that Wakefield had a conflict of interest in a lawsuit against manufacturers of the MMR vaccine. Further, a thorough scientific review by the National Academy of Sciences Institute of Medicine concluded, "the evidence favors rejection of a causal relationship between thimerosal-containing vaccines and autism."

The damage by Wakefield's sensational claims would reverberate for years. The journal Lancet finally retracted the paper in 2010, but vaccine immunization levels for measles declined in the United Kingdom and U.S.. Measles outbreaks there and in the U.S. have been reported, years after the condition was officially declared "eliminated" by both countries. Measles is extremely contagious, can lead to deafness and pneumonia and causes more than 100,000 deaths annually; it usually is only found in the developing world. But many children born in the U.K. and the U.S. in the late 1990s and early 2000s were never vaccinated because of autism fears and philosophical reasons. A July 2013 story in The Wall Street Journal sums up this cautionary tale:

> "When the telltale rash appeared behind Aleshia Jenkins's ears, her grandmother knew exactly what caused it: a decision she'd made 15 years earlier.
>
> "Ms. Jenkins was an infant in 1998, when this region of southwest Wales was a hotbed of resistance to a vaccine for measles, mumps and rubella. Many here refused the vaccine for their children after a British doctor, Andrew Wakefield, suggested it might cause autism and a local newspaper heavily covered the fears. Resistance continued even after the autism link was disproved.
>
> "The bill has now come due.
>
> "A measles outbreak infected 1,219 people in southwest Wales between November 2012 and early July, compared with 105 cases in all of Wales in 2011.
>
> "One of the infected was Ms. Jenkins, whose grandmother, her guardian, hadn't vaccinated her as a young child. 'I was afraid of the autism,' says the grandmother, Margaret Mugford, 63 years old. 'It was in all the papers and on TV.'"

Sources:

The CDC's Autism and Developmental Disabilities Monitoring (ADDM) Network *http://www.cdc.gov/ncbddd/autism/addm.html*

"Wakefield's article linking MMR vaccine and autism was fraudulent." *BMJ*, Jan. 6, 2011. *http://www.bmj.com/content/342/bmj.c7452*

Immunization Safety Review: Vaccines and Autism. The Institute of Medicine, May 14, 2004. *http://www.iom.edu/Reports/2004/Immunization-Safety-Review-Vaccines-and-Autism.aspx*

*"Fifteen Years After Autism Panic, a Plague of Measles Erupts." Jeanne Whalen and Betsy McKay, *The Wall Street Journal*. July 19, 2013. *http://online.wsj.com/news/articles/SB10001424127887323300004578555453881252798*

research to identify potential policy problems—such as global climate change—and to applied research for possible solutions to problems.

Assessing the Expert

Nullius in verba, the motto of one of the world's oldest scientific associations—the Royal Society—means literally, "take no one's word for it." Policymakers constantly hear from experts and organizations who advocate a position on a bill, regulation or study. It is important to understand the abilities and perspective of the individual(s) performing or presenting research or testimony in a hearing. To be considered a credible source, the researcher should be qualified, either through formal training or work experience, to design and conduct the study and to draw reasonable conclusions from it. The researcher should be well acquainted with the subject area and the body of technical information pertaining to it; a substantial and relevant publication record usually indicates that expertise. Although academic or professional credentials are not necessary or adequate to ensure thorough scientific conduct, the majority of qualified researchers in highly specialized fields today have earned postgraduate degrees.

If a wildlife expert is speaking on the economic ramifications or implications of a decision, that person has expertise, but only in his or her field of study. The individual may have opinions and strongly held beliefs backed up with some pertinent facts, but that person has now strayed out of a scientific realm and into the advocacy realm. Advocacy is integrally important to the democratic process and is a key externality that influences public policy. Advocacy, however, is not science and science is not advocacy. The data resulting from a study or hypothesis do not change with the party in power, nor should it be tailored—omitting key facts or advancing weak causal relationships—in order to fit a specific agenda.

Vested interest is another factor state officials should consider when gauging the credibility of a source of scientific information. Individuals who stand to benefit—either financially, politically or socially—from a particular outcome may express a bias in interpreting scientific findings. Because scientists also have an interest in maintaining their reputation in the scientific and policy communities, they have an incentive to provide reasonable conclusions that can stand up to the scrutiny of other scientists and parties affected by the policy decision. To understand the perspective of the source, state officials can question the researcher's personal or professional reasons for asking a specific scientific question.

"An important distinction must be made: Not all studies by industry and advocacy organizations should be dismissed simply because they come from a certain source."

The issues of qualifications and perspective often arise during expert testimony to legislative committees. The objective of this critical thinking strategy is to encourage policymakers to consider and understand the perspective of witnesses and the potential variables at play. This is why the ability to evaluate the quality of the data and whether the study design was appropriate for your questions and decisions is so important. State officials may determine a researcher's credentials and interests in the policy decision at hand by watching for warnings signs and asking pertinent questions of expert witnesses as outlined below.

WARNING SIGN:
Observer Bias and Vested Interest

The source's record of objectivity is important in determining a study's soundness. Even unconsciously, predispositions can shape interpretation of study results. In addition to questioning experts about their biases, state officials can be more confident of a study's objectivity if the scientific community has reviewed it.

Example: Suppose Mr. Greenthumb (from the earlier example) is promoting plants from his shop for being of a superior quality because he talks to them on a daily basis. The conclusions he drew from his experiment may have been biased as a result of his efforts to prove his claim and sell more plants.

WARNING SIGN:
The Presenter Released Findings Directly to the Media

Typically, the common practice among scientists is to delay release of a study's findings to the public until it has gone through the peer review process (more is available in the "Integrating the Knowledge" section of this guide). For example, the New England Journal of Medicine's editorial policy abides by the so-called "Inglefinger Rule," which delays a media release in order to conduct peer review and provide more time to review studies that may have minor mistakes that could be misinterpreted by the media due to their complex nature. There is, however, a robust debate over public access and media embargos by those seeking a right to know.

Example: Mr. Greenthumb decides, for either economic or personal reasons, to promote his findings that his

experiment of talking to plants really does increase their growth rates through a press release picked up by the local newspaper, rather than submitting his study to a journal where trained botanists could analyze his methods and conclusions.

Questions to Ask about the Expert:

- **What educational background or training does the expert have?**
- **What types of work has the expert done in the field?**
- **Does the source of the research have anything to gain by the study's outcome? Are there conflicts of interest either financially or professionally?**
- **Is the expert or the expert's employer concerned about implications of a policy/decision?**

Assessing the Methods

Credible scientific conclusions are based on well-established research practices. The principles of the scientific method provide key indicators of a sound process. For example, the study should describe the methodology used in the experiment in a manner that enables others to repeat the test—and verify the results.

All studies and modeling work contain some type of built-in assumptions. Those assumptions are not always causes for concern. Assumptions are justifiable by performing tests of the hypothesis in conjunction with experimental tests that can be verified separately. State officials should ask about underlying assumptions made in a study to ascertain the need for its inclusion and whether scenarios or variables considered can withstand scrutiny in real world applications. For example, a study warning about the dangers of the very rare cases of caffeine overdoses should include information about the ingestion levels that would warrant public action and concern. To reach fatal levels of caffeine toxicity in the blood, which is 5 to 10 grams depending on weight and health factors, a person would have to consume roughly 42, eight-ounce cups of coffee at one sitting.

Standards of reference also are important when deciphering the conclusions of a scientific study. When a researcher reports the population of an endangered species has tripled during the past five years, knowing the original population contained five individuals rather than 500 changes the context of these findings. If a survey shows 80 percent of its respondents favored the return of gallows to public courtyards, it would be helpful to know the pollsters only surveyed corrections employees.

WARNING SIGN:
Important Variables That are Overlooked or Ignored

A variable is something that changes, or a factor that may influence the outcome of an experiment. When trying to prove one thing is related to another, researchers may overlook certain variables that may shape the outcome. For instance, a generalization that "hungry dogs are more dangerous" ignores such important factors as the breed of the dog or the way it has been trained. Officials should question whether the study was controlled for other likely variables.

Example: It's possible that Rooms A and B in Mr. Greenthumb's plant experiment did not provide identical environments for the plants. Perhaps the shop owner ignored the fact that a humidifier was located in Room A, providing more moisture for those plants, which led to their faster growth rates.

WARNING SIGN:
Inadequate Sample Size and Biased Sample Collection

Studies based on an inadequate or biased sample may produce misleading conclusions. If a scientific study examines too few subjects, its results cannot be generalized to an entire population. The size of test samples varies according to such factors as the size of the overall population of interest. For example, a study of a relatively rare form of cancer (e.g., pancreatic cancer) can be based on a much smaller sample size than a common cancer (e.g., lung cancer). To increase the likelihood the sample accurately represents diversity in the entire population, researchers should select their samples randomly. State officials should ask how the sample was selected and if it compares in size to those of similar studies. They may need to request further explanation if the sample composition seems biased or the sample size seems small. They also should question studies that do not state the number of subjects studied or experiments repeated.

Example: Mr. Greenthumb only tested his hypothesis on 30 plants of his total inventory of 2,000 plants. He may not be able to conclude reasonably that his results apply to all 2,000 of his plants based on the relatively small sample size.

WARNING SIGN:
Lack of Helpful Standards of Reference

Percentages that are reported without good standards of reference or baseline data can be misleading. Officials should ask what the outcomes would be for the normal or expected case if such guidelines were not included. A clear understanding of how different the study's outcomes were from those normally expected can help officials interpret the findings accurately.

Example: Mr. Greenthumb's plants measured 4 inches at the beginning of the experiment. But if the type of plant grows faster at a more mature phase, say 8 inches tall, he must take that into account. If he doesn't, he should conclude there is little confidence his experiment produced significant findings because the fact that the plant's growth rate changes as it matures was not documented within the experiment.

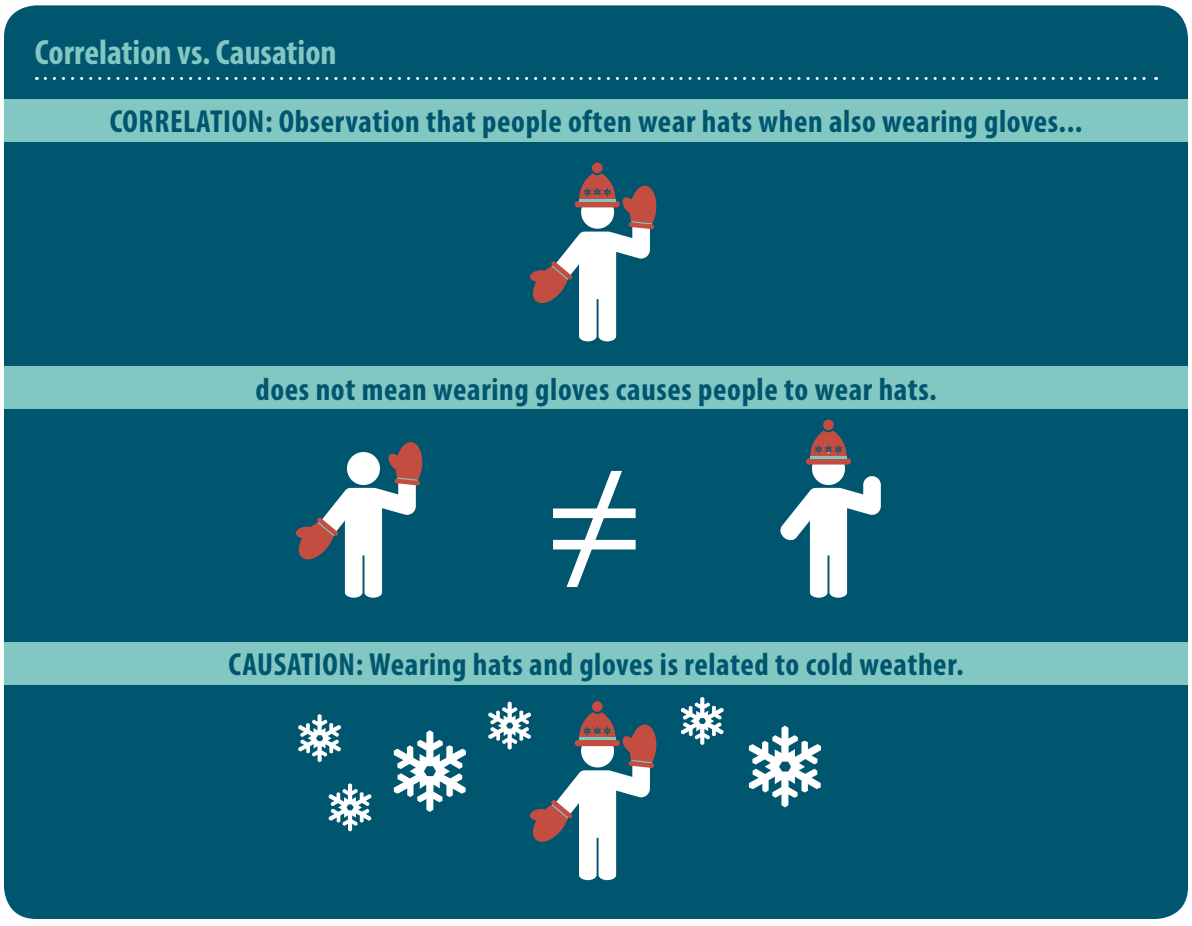
Questions to Ask about the Methods:

- **Who gathered this information?**
- **What specific data or studies form the basis of the researcher's scientific conclusions?**
- **Have the data or studies been evaluated by other scientists? How extensive was the review?**
- **Have important variables been overlooked or ignored?**
- **Is the sample size used in the study truly representative?**
- **What specific hypotheses or questions did the researchers set out to test? Were steps taken to control other effects?**

Assessing the Results

Clear data analysis should explain the relationship between the results and the original hypothesis. If a study does not include such analysis, state officials should ask questions to determine why particular steps were omitted.

A scientific study should indicate the type of relationship between variables it demonstrates either correlation or causation. Correlation, also known as association, is an apparent connection between two variables, assumed when they frequently occur together. For example, the observation that people often wear hats when they also are wearing gloves does not mean that wearing gloves causes people to wear hats. The wearing of both hats and gloves are related to another factor—cold weather. Causation is a statement of cause and effect, which means changes in one variable directly cause a particular change in another variable. Statements of causality often take the form of "if, then" statements. For instance, if you touch a hot stove, then you will burn your hand.



"Although scientists disagree on the procedure for proving causation, most agree the ability to show 'A causes B' is one of the most powerful statements scientists can make."

Studies that use true experiments, which control the presence of the independent variable (the hot burner) to determine its impact on the dependent variable (the hand) seek to establish causal relationships. Other studies only try to identify a correlation between variables. For example, epidemiological research, which studies the incidence of disease in humans to control health problems, often identifies situations in which variables such as poor eating habits and disease tend to occur together. State officials should make sure the study's conclusions agree with the degree of association the research was designed to identify.

To determine if the observed results of a study are likely be true, scientists employ a technique called statistical significance that measures the relationship between two variables to determine if the results are likely to occur or did so by happenstance. This mathematical measure determines if an observed difference is occurring by chance through an expressed value. The smaller the value, the less likely the results are occurring by chance and more likely the results are accurate.

Although it is tempting to skip over such technical details, policymakers should pay attention to the statistical terms that illustrate the degree of certainty associated with scientific findings. These statements indicate the degree of confidence with which scientists can present their conclusions. Statistical measures of confidence—standard deviation, standard error or confidence intervals—indicate the degree of certainty in the study's results. For instance, confidence intervals define the range within which results must fall in order to support the hypothesis. In some cases, state officials may be comfortable basing policy decisions on less stringent confidence measures than those required by the scientific community. Further, a careful consideration of abbreviations, acronyms and terms is critical when considering the proportionality of a study's findings. For example, the difference in a common measure of toxicity in the environment—parts per million vs. parts per billion—is enormous. One part per million of a substance in water would be equal to one teaspoon per 1,000 gallons, while one part per billion of a substance in water would be the equivalent of one teaspoon per 1 million gallons.

Conceptualizing Toxicity and Understanding Acronyms

The effects of harmful and toxic substances to the environment and public health are related to the amount of exposure or dose. Some chemicals can cause toxicity even at very small levels, but it is critically important to understand how those doses are described and relate to one another compared to the substances we are exposed to every day. Most interactions we have with chemicals are not in a pure form; usually, it's through the air we breathe, the food we eat and the water we use.

The overall amount of a toxin in a given substance is referred to as its concentration. To determine a chemical's concentration for a lake, for example, a scientist takes a small water sample that can be compared in a relative term with the lake's total volume. Those are usually expressed as parts per million, or ppm, parts per billion, or ppb, and parts per trillion, or ppt. Below is an analogous chart showing what these amounts would demonstrate in time, money, distance and weight.

1 ppm	1 ppb	1 ppt
1 teaspoon per 1,000 gallons of water	1 teaspoon per 1 million gallons of water	1 teaspoon per 1 billion gallons of water
1 second in 11.5 days	1 second in 31.7 years	1 second in 317.1 centuries
1 penny out of $10,000	1 penny of $10 million	1 penny of $10 billion
1 inch of 15.8 miles	1 inch of 15,782.8 miles	1 inch of 657.6 trips around the equator
1 minute in 1.9 years	1 minute in 19 centuries	1 minute in 1,900 millenniums
1 ounce in 62,500 pounds	1 ounce in 31,250 tons	1 ounce in 31,250,000 tons

Source: "What is the Significance of a Part Per Million?" Frederick M. Fishel and Mark Mossler, University of Florida Institute of Food and Agricultural Sciences (2013). *http://edis.ifas.ufl.edu/pi116*

WARNING SIGN:
Correlation Confused with Cause and Effect

Even if two events occur together, one may not be the actual cause of the other. Both may be related to another factor that is the true cause. If a study or expert does not clearly establish an intended cause-and-effect relationship, officials should ask questions to determine if the evidence has confused correlation with causation.

Example: A study finds the number of drowning deaths in the U.S. increases with amount of domestic ice cream sales. The author suggests the consumption of ice cream causes drowning and recommends consumption be curtailed. In this case, the author did not account for seasonal and temperature changes where consumers buy more ice cream in warmer weather, which also happens to correspond with vacation season and more trips to the beach or pool. Another useful example illustrating the confusion of correlation with causation would be a report issued by a group tracking the rates of autism diagnoses and increased sales of organic food. Both have increased substantially from the late 1990s through 2011, almost on the same exact linear curve, yet the information is completely coincidental and insignificant.

WARNING SIGN:
Conclusions Based on Personal Stories or Anecdotal Evidence

People often draw incorrect conclusions from personal stories, especially when they are presented in a familiar or appealing way. Although many public speaking courses emphasize the importance of personalizing a speech or debate to make it more convincing, personal stories or testimonials cannot be applied universally. Officials should be sure they draw conclusions from well-designed scientific studies, rather than from anecdotal information.

Example: Suppose Mr. Greenthumb was particularly fond of a large plant he enjoyed talking to, and he strongly believed the plant responded to his voice by growing. His marketing claim then would be based on anecdotal evidence, with no scientific proof to support his assertions.

WARNING SIGN:
Statements of Certainty

Though based on the best evidence available at the time, scientific statements cannot be 100 percent certain. Thus, conscientious scientific communicators rarely use absolute terms such as always, only or never. Instead, they explain the study's limitations—such as which unmeasured variables may have influenced the results—and communicate the degree of certainty in their findings—statistical measures of confidence. When considering whether results are meaningful, state officials can examine and seek clarification on such measures to discern the level of statistical significance.

Example: Suppose a sign outside Mr. Greenthumb's store proclaims, "The Fastest-Growing Plants in the Business—They Thrive on Conversation!" The absolute term, fastest, should serve as a signal for the need to question and examine his evidence.

Questions to Ask about the Results:

- **Has the research been reviewed by other scientists and interested parties? How extensively?**
- **What are the underlying systematic uncertainties?**
- **Were conclusions based on personal stories/anecdotal evidence?**
- **Do the results demonstrate causality rather than correlation? Are the results statistically significant?**
- **Are statistics adequately explained? If not, ask for a practical explanation.**
- **What degree of uncertainty surrounds the results?**
- **To whom or for what do the results apply? Can they be extrapolated to the general population?**
- **Do the conclusions logically follow from the scientific results?**

INTEGRATING THE KNOWLEDGE

Once a policymaker has gathered technical information and questioned experts, the final step in the decision-making process is integrating individual pieces of knowledge into a coherent plan of action. Helpful ways to refine that process include a robust peer review process, the utilization of risk assessments and the concept of adaptive management.

Peer Review

According to the Environmental Protection Agency's Peer Review Handbook, "Peer review is a documented critical review of a specific Agency's scientific and/or technical work product. Peer review is conducted by qualified individuals (or organizations) who are independent of those who performed the work, and who are collectively equivalent in technical expertise (i.e., peers) to those who performed the original work. Peer review is conducted to ensure that activities are technically supportable, competently performed, properly documented, and consistent with established quality criteria."

During this process, other scientists assess such qualities as the relevance, accuracy and reliability of the study. Peer review typically is required for accepting publishable articles, awarding grants and approving tenure. Although it is not always perfect and cannot guarantee fraud or error will be uncovered, peer review is traditionally the best mechanism many scientific journals and funding agencies have to avoid publishing or financing poor quality research.

Publication of scientific findings often follows peer review and is an integral component of research, as it further distributes the findings to those in the scientific community, enabling them to assess, correct and develop the research results. Once a study is published, further response is likely, and state officials can use this as additional evidence.

Traditional review periods for publication in scientific journals may be up to two years or longer, depending on the prestige of the journal and competition levels within the discipline. Online publishing has greatly accelerated these timelines to allow for greater access by the scientific community, which then can analyze findings. When studies are released without peer review to a news-hungry press, researchers may have to retract their findings if other scientists find fault with their study. The consequences of scientifically unsupported decisions creates lasting misperceptions—as the earlier case study of the autism/vaccine illustrated—that may be difficult to reverse.

Several practical limitations on peer review and publication may explain why some sound studies do not meet these standards. For instance, proprietary research data, such as studies conducted by and for federal regulatory agencies or by private companies, are unavailable to the general public for peer review. Such studies are usually undertaken by industry, in some cases for the government, and held as confidential business information. Additionally, Internet publishing presents a relatively new dilemma for adequate peer review. Some scientific journals are beginning to publish articles almost instantaneously, with continual review following publication.

Risk

Risk is an inherent part of everyday life; it can be defined as the potential for harm for humans or the things they value. Scientists have developed a process for dealing with uncertainties to quantify the risk and potential damage or harm to public health, the environment, consumer products, infectious diseases, and on and on. This process is conducted through a risk assessment that characterizes and measures the magnitude and nature of potential threats.

Publications and Typical Peer Review

Professional journals: usually peer-reviewed; one to three years to publication; contain technical jargon.

Conference proceedings: usually no peer review; six to eight months to publication; contain technical jargon.

Textbooks: peer review level varies; average one year to publication; may contain defined technical jargon.

Newspapers and popular magazines: typically no peer review by scientific community; days to weeks for publication; seldom contain technical jargon.

Consensus conference or scientific review panels: convened to address specific topics and reach conclusions about the state of the science; one to two years with various outlets for publication.

Source: "Using Scientific Input in Policy and Decision Making." Paul W. Adams and Anne B. Hairston. Oregon State University, August 1995.

The concept of risk assessments has been around for many years and is used in a variety of applications with distinct fields of specialization by professionals. The first formal attempt to characterize risk assessments was undertaken by the National Academy of Sciences and the National Research Council in 1983 with the publication of its first Redbook. In 1994, the National Academy of Sciences further refined its original intent of charactering risk assessments by defining it as:

> "… The integration of information from the first three steps of the risk assessment process, as defined in the 1983 NAS 'Redbook,' to develop a qualitative estimate of the likelihood that any of the hazards associated with the agent of concern will be realized in exposed people. This is the step in which risk assessment results are expressed. Risk characterization should also include a full discussion of the uncertainties associated with the estimates of risk."

Risk assessment conducted by the Environmental Protection Agency for both environmental and public health concerns are conducted in basically the same five-step process.

» Step 1—Planning and scoping. Who/what/where is at risk? What are the hazards of concern? Where do they come from? How does exposure occur? What populations are impacted? What are the health effects? What duration of exposure will cause a harmful effect? What are the lifetime effects from exposure?
» Step 2—Hazard identification examines whether a stressor has the potential to cause harm to humans and/or ecological systems, and if so, under what circumstances.
» Step 3—Dose response assessment examines the numerical relationship between exposure and effects.
» Step 4—Exposure assessment examines what is known about the frequency, timing and levels of contact with a stressor.
» Step 5—Risk characterization examines how well the data support conclusions about the nature and extent of the risk from exposure to environmental stressors.

State officials must understand the distinction between a risk assessment, which calculates the hazard and its consequences, and risk management, which is a process that decides if and how a hazard should be addressed. The risk management process inherently involves policy decisions and external forces, such as public input, to ultimately determine acceptable risk levels. Part of that challenge for policymakers is articulating the potential risks to the environment and public health. Scientists and technical professionals often perceive risk differently than the average person who likely is unfamiliar with conflicting interpretations of data, jargon-laced language, and the absence of absolute answers that often accompany risk assessments and studies. State officials can help in this process by focusing their communication efforts in three main areas: what is known, what is not known and what can be done to address concerns.

One potential direction that could tie the disparate areas of risk assessment, risk management and risk communication together is a set of guiding principles first developed in 1995 by a federal interagency working group

A Framework for Risk Management

1. Issue identification: identify the health, environmental, social, economic, cultural, legal, political and other issues that will be considered in developing the management strategy.
2. Goal-setting: establish health or ecological goals that broadly incorporate issues and concerns raised during the issue identification process.
3. Management options development: devise a range of possible risk management strategies that consider the issues and concerns identified in the first step.
4. Data compilation and analysis: identify, collect and analyze relevant data on the scientific, technical, economic, social, cultural, legal and political aspects of the options.
5. Option selection: decide on a preferred management strategy, scaled to the risk under consideration and based on analytical review of the data and input from those involved.
6. Decision implementation: initiate hazard control/remediation and/or exposure reduction activities designed to implement the preferred management strategy.
7. Tracking and evaluation: collect and analyze monitoring and assessment information and compare against baseline data and target outcomes developed during previous steps.

Source: "A Multi-Stakeholder Framework for Ecological Risk Management: Summary." R. Bachman. SETAC Technical Workshop, Society of Environmental Toxicology and Chemistry, 1998.

led by the Office of Management and Budget and the Office of Science and Technology Policy. The agencies reaffirmed those basic principles in 2007 to guide policymakers in assessing, managing and communicating policies to address environmental, health and safety risks. Risk analysis was just one very important tool that needed to "retain sufficient flexibility to incorporate scientific advances." The principles are as follows:

Risk Assessments

» Agencies should employ the best reasonably obtainable scientific information to assess risks to health, safety and the environment.
» Characterizations of risks and of changes in the nature or magnitude of risks should be both qualitative and quantitative, as well as consistent with available data. The characterizations should be broad enough to inform the range of policies to reduce risks.
» Judgments used in developing a risk assessment—such as assumptions, defaults and uncertainties—should be stated explicitly. The rationale for these judgments and their influence on the risk assessment should be articulated.
» Risk assessments should encompass all appropriate hazards. In addition to considering the full population at risk, the assessment should direct attention to subpopulations that may be particularly susceptible to such risks and/or may be more highly exposed.
» Peer review of risk assessments can ensure the highest professional standards are maintained. Therefore, agencies should develop policies to maximize its use.
» Agencies should strive to adopt consistent approaches to evaluating the risks posed by hazardous agents or events.

Joint Fact Finding: A Case Study

The Bay Delta sits at the juncture of the Sacramento and San Joaquin rivers at the mouth of San Francisco Bay. It represents the largest estuary on the West Coast of North and South America. The delta supports a variety of plants, migratory birds, endangered fish species and many other animals. It also supplies water for agriculture, the high-tech industry and 22 million California residents.

The CALFED Bay-Delta Program, a unique collaboration among 25 state and federal agencies, was created in 1995 via a negotiated agreement among state and federal governments and various stakeholders. It was charged with identifying options to improve agricultural water use efficiency while restoring the ecosystem, particularly in the face of chronic droughts. Initial attempts to address this complex set of issues were unsuccessful, in large part because of disagreement over scientific and technical information. Facing a critical deadline in 1998, CALFED hired an impartial public policy mediator to help design and facilitate a more effective process.

The mediator convened the Independent Review Panel on Agricultural Water Conservation. It included five nationally recognized scientists with expertise in conservation, hydrology, hydraulics and aquatic ecology. The panel also included technical advisers aligned with various stakeholder groups. Before assembling the panel, the mediator worked closely with stakeholders, decision-makers and experts through one-on-one conversations, meetings with like-minded interests and a one-day public scoping meeting, to identify what was known, what was not known and what information was needed to make an informed decision.

The expert panel convened for two and a half days at the end of 1998. The deliberations succeeded in identifying and narrowing the areas of scientific uncertainty and disagreement and producing new information that explained causal relationships relevant to managing the resource. The panel generated a revised approach to water conservation that relied on incentives and objectives rather than best management practices. The panel also identified areas in need of further data collection and analysis.

The mediator drafted a single-text document summarizing the panel's findings with input from all panelists. The report became a source for ongoing deliberations and was critical in formulating CALFED's Water Use Efficiency Program, which was accepted by a wide range of stakeholders and policymakers.

This case demonstrates several key components of joint fact-finding. Facilitated by an impartial mediator, the process resulted in the coproduction of policy-relevant, technical information accepted by a range of stakeholders—an outcome many believed would be impossible after the failure of initial attempts to address agricultural water use. Stakeholder involvement during the scoping and selection process, transparency of the panel's deliberations and production of a single text of recommendations all contributed to the salience and credibility of the panel's findings.

Source: "Sustainable Water and Environmental Management in the California Bay–Delta." National Research Council. The National Academies Press, 2012.

Risk Management

» In making significant risk management decisions, agencies should analyze the distribution of the risks and the benefits and costs—direct and indirect, quantifiable and nonquantifiable—associated with the selection or implementation of risk management strategies.

» In choosing among alternative approaches to reducing risk, agencies should seek to offer the greatest net improvement in total societal welfare, accounting for a broad range of relevant social and economic considerations, such as equity, quality of life, individual preferences, and the magnitude and distribution of benefits and costs—direct and indirect, quantifiable and nonquantifiable.

Risk Communication

» Risk communication should involve the open, two-way exchange of information between professionals, including policymakers, experts in relevant disciplines and the public.

» Risk management goals should be stated clearly, and risk assessments and risk management decisions should be communicated accurately and objectively in a meaningful manner.

» To maximize public understanding, explain the basis for significant assumptions, data, models and inferences used or relied upon in the assessment or decision; describe the sources, extent and magnitude of significant uncertainties associated with the assessment or decision; make appropriate risk comparisons, taking into account, public attitudes with respect to voluntary versus involuntary risk; and provide timely, public access to relevant supporting documents and a reasonable opportunity for public comment.

Adaptive Management

Adaptive management is another important strategy to make informed choices and resolve disputes over scientific and technical information. According to Kai Lee, one of the founders of this strategy, adaptive management is a process of making public decisions using the best information, monitoring the results, learning from experience and adapting future policy prescriptions appropriately. It is based on the premise that uncertainty is a given—social, economic and environmental values change, landscapes evolve and unanticipated consequences occur. This does not mean decisions should be postponed until more complete information is available. It means policymakers should learn by doing and should create an expectation of learning from experience as the decision-making process unfolds.

Principles to Resolve Science-intensive Disputes

The following four principles have proved to improve public decisions characterized by contested science.

Clarify the questions jointly before gathering more data—Too often, we find ourselves in disputes where data exists but people still feel their questions aren't being answered. One problem may be that people are not yet clear about what questions they care about. The key is to gather experts, decision-makers and stakeholders and have them determine jointly which questions are part of the scope of the discussion. Because different people may see the questions differently, this often means seeking answers to questions of importance to each individual in the group.

Focus on decision-relevant information—The problems that confront policymakers clamor for good information. But in some cases, different advocates may be shouting so loudly about their own data that they can't hear each other. Once the participants have agreed on the questions, they also need to discuss and agree on what information is needed to answer those questions. With that as a foundation, people often are better able to review existing information, determine what they agree on and focus any further data collection or analysis on filling agreed-upon gaps.

Let science be science, and don't confuse it with policy—Science is needed to inform policy, but the choice of what information to collect and why is almost always shaped to some degree by someone's values and priorities. In each case, it is critical to clarify who set the underlying assumptions and whether policymakers and stakeholders helped shaped the questions being researched. Too often, leaders look to scientific information that was gathered for other reasons. Too often, also, we look to science for answers it doesn't have; science cannot tell policymakers what tradeoffs to make or how much risk to accept. Though there's no requirement for scientific certainty, policymakers should be wary of setting policy before the science is clear enough to inform sound policy decisions.

Learn together—Decision-makers and advocates should view the policymaking process as one of inquiry—clarify questions, ask what information is needed, identify what information exists and what is needed, create a process for data collection and analysis, decide who will conduct the studies, and learn from the results. This process of collaborative inquiry does not need to be burdensome, but it does need to be intentional. It may require as little as a few meetings or workshops or it could require the investment in a joint technical working group.

Sources:
"A Dialogue, Not a Diatribe: Effective Integration of Science and Policy Through Joint Fact Finding." Herman A. Karl, et al. *Environment*, 2007, p. 29.
"Building Trust: When Knowledge from Here Meets Knowledge From Away." Peter S. Adler and Juliana E. Birkhoff. The National Policy Consensus Center. *http://www.policyconsensus.org/publications/reports/docs/BuildingTrust.pdf*

WARNING SIGN:

Peer review and publication are helpful tools for verifying scientific findings. Once a study has survived the scrutiny of peers in the scientific field, nonscientists can be more confident of its soundness. Since publication leads to further peer review, it is often more difficult to assess the technical quality of findings that are so recent they have not been published. State officials should ask for documentation of peer review or for the published study. If neither is available, officials can question the expert to determine if there are satisfactory reasons, such as protecting proprietary information, the scientific community has not reviewed the study.

Example: Mr. Greenthumb's findings have not been reviewed or tested by any other botanists for accuracy of his methods or conclusions. If the warning signs outlined indeed applied to his study, the scientific community should have questioned Mr. Greenthumb's study, perhaps opposing its publication. Without peer review and publication, a nonscientist must judge Mr. Greenthumb's claims without the expertise of the scientific community.

Questions to Ask about Integrating the Knowledge:

- **Have the study results been published? If yes, was it in a journal that requires peer review prior to publication? Have any scientific peer review panels considered the study results?**
- **Is there a consensus about the key findings of the studies? What are the areas of agreement/disagreement?**
- **Do other scientists share the researcher's views? Who doesn't and why?**
- **Have the results been repeated, confirmed or supported by other studies?**
- **What are your views on the practical applications of this scientific knowledge/decision?**
- **Is the timeliness of the study relevant to today's issues?**
- **What are the consequences/implications of action or inaction, including risks? Is there a balanced approach? Why or why not?**

Adaptive Management

Although its roots extend into many disciplines, adaptive management's broad features are based on research conducted by ecological scientists in the early and mid-1970s. The concept gained greater currency in U.S. federal water and science agencies during the 1990s. Current federal law mandates the Florida Everglades restoration project be managed under an adaptive management rubric, the federal science and management program for the Colorado River below Glen Canyon Dam is framed by adaptive management principles, and the U.S. Army Corps of Engineers is promoting the concept as a guiding principle in managing the Missouri River dam and reservoir system.

Adaptive management is interdisciplinary, has a strong theoretical component and represents a departure from traditional management approaches in many ways. The adaptive management paradigm views management actions as flexible and amenable to adjustments. It emphasizes careful monitoring of economic and environmental outcomes of management actions. It also seeks to engage stakeholders in a collaborative learning-while-doing process. Other differences are:

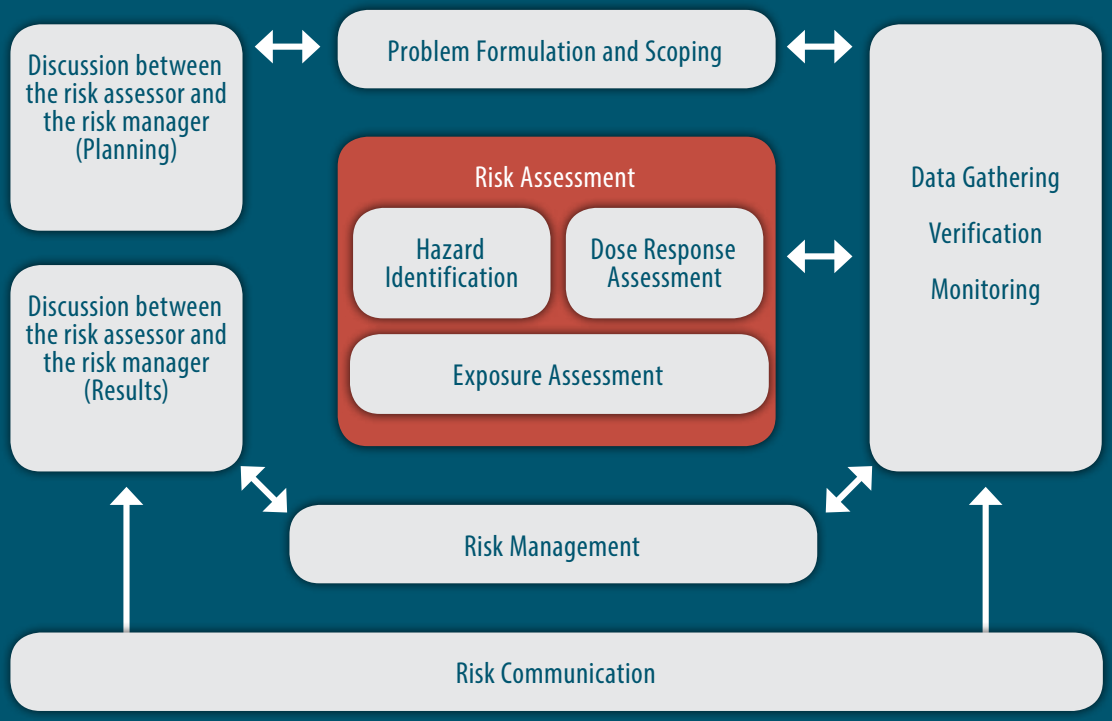
Traditional Management	Adaptive Management
Seek precise prediction	Uncover range of possibilities
Build prediction from detailed understanding	Predict from experience with aggregate responses
Promote scientific consensus	Embrace alternatives
Minimize conflict among actors	Highlight difficult tradeoffs
Emphasize short-term objectives	Promote long-term objectives
Presume certainty in seeking best action	Evaluate future feedback and learning
Seek productive equilibrium	Expect and profit from change
Public provides input in pre-project discreet events	Public input is changing and frequent
Public interest is perceived as aggregate	Public interest perceived as pluralistic

Source: *Compass and Gyroscope: Integrating Science and Politics for the Environment*. Kai N. Lee. Island Press, 1993. pp. 243.

Conclusion

Science informs just one part, albeit a critically important one, of the policymaking process; it is not a policy itself. Sometimes there simply is no clear-cut answer science can provide to determine consensus. One tool utilized by practitioners in the energy and natural resource policy arena is joint fact finding, where an agency or group of agencies will act as a convener and final decision-maker. Its mission, however, is to engage stakeholders and nongovernmental participants in a formal discourse meant to resolve issues using quality and verifiable science. Ultimately, the choices made in resolving complex technical issues reside in a leader's ability to collaborate, dialogue and engage—no easy task in today's hypercharged political environment. This guide is intended to help make that process less daunting and facilitate better outcomes that could be applied across a host of policy discussions.

Risk Management Model



Sources:
"A Multi-Stakeholder Framework for Ecological Risk Management: Summary." R. Bachman. SETAC Technical Workshop, Society of Environmental Toxicology and Chemistry, 1998.
U.S. Environmental Protection Agency Risk Characterization Handbook. December 2000, p. 5–7 *http://www.epa.gov/spc/pdfs/rchandbk.pdf*

GLOSSARY

Alpha Level A level set to determine significance in research experiments. The set alpha level represents the probability (in 100) that the results could be due to chance. Most alpha levels range between 0.05 and 0.10 (5 percent to 10 percent). When a significant result is achieved at the 0.05 alpha level, there is a 5 percent chance that results were due to a chance occurrence and were not due to the experimental effect. See also statistical significance.

Baseline A preliminary measurement of behavior, health or mechanisms before experimental manipulation.

Bias An inclination that inappropriately influences a researcher's judgment. Also, a systematic error introduced into sampling or testing by selecting or encouraging one outcome or answer over others.

Carcinogen A substance or agent that produces or incites cancer.

Cohort A group of individuals having a common statistical factor in a demographic study.

Confidence Interval An estimated range of values that is likely to include an unknown population parameter, with the estimated range being calculated from a given set of sample data. For example, if a survey has a margin of error of plus or minus 4 percent at the 95 percent level of confidence, then in 95 out of 100 samples like the one used in the survey, the results obtained should be no more than 4 percentage points above or below the figure that would be obtained by interviewing the entire population being sampled. The width of the confidence interval gives some idea about how uncertain the researcher is about the unknown parameter. Confidence intervals are typically set at 95 percent (a 10 percent range), but they could be set at wider or smaller widths, such as 90 percent or 99.9 percent. See also margin of error, parameter.

Conjecture Inference from defective or presumptive evidence.

Cost-benefit Analysis A formal quantitative procedure comparing costs and benefits of a proposed project or act under a set of pre-established rules. To maximize absolute return given limited resources, benefits-costs is the appropriate form.

Data Numbers or measurements that are collected as a result of observations or experiments.

Deduction Formulation of particular conclusions from general or universal premises.

Dose-response A correlation between a quantified exposure (dose) and the proportion of a population that demonstrates a specific effect (response).

Ecological Impact The total effect of an environmental change, natural or man-made, on the community of living things.

Ecological Significance When a change that is detected or projected in the ecological system or its individual components of concern is a change of importance to the structure, function or health of the system and the change exceeds the context of natural variability.

Extrapolation In risk assessment, this process entails assuming a biologic fact based on observable responses and developing a mathematical model to describe the fact. The model may then be used to extrapolate to response levels that cannot be directly observed.

Falsification In research terms, refers to changing or misrepresenting data or experiments or credentials.

Geographic Information System (GIS) A computer based system for the capture, storage, retrieval, manipulation, analysis and display of geographic information. The number and type of applications and analyses that can be performed by a GIS are as large and diverse as the available geographic data sets.

Induction Reasoning from specific observations and experiments to more general hypotheses and theories.

In Vitro Laboratory experiments on cells or tissue samples.

In Vivo Laboratory experiments on small living animal subjects.

Latency Period The period of time from exposure to an agent to the onset of a health effect.

Longitudinal Studies A long-term study that repeatedly samples the same study group over an extensive period of time, with some lasting several generations. Most often conducted to measure long-term effects or to detect changes those researchers believe take time to manifest.

Lowest Observable Effect Level (LOEL) The smallest dose that causes any detectable effect; one of the threshold levels of exposure when measuring the effects of non-carcinogens.

Margin of Error A measurement of the accuracy of the results of a survey. For example, a margin of error of plus or minus 3.5 percent (+/- 3%) means that there is a 95 percent chance that the responses of the target population as a whole would fall somewhere between 3.5 percent more or 3.5 percent less than the responses of the sample (a 7 percent spread).

Mean The sum of scores or values of a variable divided by their number.

No-Observed-Adverse-Effect Level (NOAEL) The dose at or below which no harmful effects are detected; one of the threshold levels of exposure when measuring the effects of non-carcinogens.

No-Observed-Effect Level (NOEL) The dose at or below which no biological effects of any type are detected; one of the threshold levels of exposure when measuring the effects of non-carcinogens.

Normal Distribution Maps the range of results or scores along a "normal" or average continuum; most often associated with IQ scores in conjunction with the standard deviation. See also standard deviation.

Null Hypothesis The expectation in every study that is tested against. The null hypothesis typically states that the independent variable will have no discernible effect on the dependent variable when compared to chance.

Parameter A value summarizing a measurable characteristic of a population. The population's mean is a commonly used parameter. See also mean.

Population A complete set of individuals, objects or measurements having some common observable characteristic (e.g., all babies born in a given year). A population may include a theoretical set of potential observations (e.g., all babies regardless of when they were born or will be born).

Population at Risk A limited population that may be unique for a specific dose-response relationship.

Random Sample A subset of a population selected in such a way that each member of the population has an equal opportunity to be selected. The goal is that the sample accurately reflect all the characteristics of the population from which it was drawn so that inferences about that population can be made from the sample.

Replication Practice by which studies are substantiated by being repeated in other laboratories. A fail-safe method that adds credibility to a study if supporting data are found or refutes the study if its results are not supported.

Social Science The study of human affairs at the level of the intact organism. Fields of social science include psychology, sociology and political science.

Standard Deviation The average deviation from a given mean, indicating how closely various samples come to the mean. See also mean.

Standard Error An estimate of the standard deviation of sample means, based on the data from one or more random samples. The smaller the standard error for a particular data set, the more precise the estimates will become, which means that increasing the sample size is one way to increase the precision of statistical decisions.

Statistical Significance A finding (e.g., the observed difference between the means of two random samples) is described as statistically significant when it can be demonstrated that the probability of obtaining such a difference by chance alone is relatively low. Common significance levels are 0.05 and 0.01. See also alpha level.

True Experiment A study in which the independent variable is under the control of the experimenter.

Valid Measurement of whether a scientific study is well grounded and justifiable. Valid studies measure and reach conclusions on the variables studied.

Variable A characteristic or phenomenon that may take on different values.

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