AAC&U’s Scientific Thinking and Integrative Reasoning Skills (STIRS) Framework

The AAC&U’s Scientific Thinking and Integrative Reasoning Skills (STIRS) framework is designed to guide the development of curriculum in evidence-based thinking for all undergraduates. The STIRS framework has been developed, used, and revised as part of the LEAP Challenge leading to capstone curriculum and signature work. The STIRS project has been developed as an exemplar of integrative liberal education.

The STIRS evidence-based thinking framework consists of four components designed to fit together as part of an integrative bachelor’s degree. The four components are

1. Evidence what it is and how it is used- Definition and uses of evidence across the disciplines
2. Research Methods- Obtaining and ensuring the quality of the evidence
3. Evidence-based Problem Solving- Using evidence to define and solve problems
4. Evidence-Based Decision Making- Using evidence to define options and make decisions

A variety of models can be used to integrate and link the components throughout the course of a bachelor's degree such as using an evidence-based thinking "Guided Learning Pathway". An initial general education curriculum covering component 1 should be expected of all students. Component 1 can serve as the basis for articulation and transfer between institutions. Component 1 should define and illustrate the use of evidence in a wide range of disciplines selected from the sciences, social sciences, health, humanities, and the fine arts. It should introduce students to the thinking processes in multiple disciplines and help them appreciate the fit between the discipline and their own interests and talents. Component 1 provides the “cornerstone” upon which the subsequent components can be built.

Connecting evidence-based thinking with the major is the aim of the second component i.e. Research Methods. Component 2 can serve as the "connector" integrating evidence-based thinking into a variety of majors and/or concentrations and facilitating the accomplishment of the remaining components. The Research Methods component is intended to provide generic research skills applicable to a wide range of disciplines. Discipline specific skills may enhance the skills outlined in component 2.

"Capstone" or synthesis activities, ideally including a signature work, can provide experience applying the problem solving and/or decision making skills outlined in components 3 and 4. Together the STIRS evidence-based thinking framework is designed to ensure a coherent approach to presenting and integrating the four components of the STIRS framework over the course of a bachelor’s degree.
The goal of the LEAP Challenge and STIRS is to graduate engaged and productive citizens prepared to address the critical challenges of the 21st century. Graduates in all fields of study need to be able to:

- Describe the range of definitions and uses of evidence in the sciences, social sciences, health, humanities and fine arts including identifying common ground and interdisciplinary approaches
- Describe qualitative and quantitative study designs and inferential reasoning principles, and other relevant frameworks, to obtain and evaluate evidence in a variety of disciplines.
- Discuss how evidence can be used to advance knowledge and/or to inform subsequent research.
- Apply an evidence-based problem solving approach which moves from problem identification, to identification of causal factors, to evidence-based recommendations for solutions, to implementation and evaluation of outcomes including the role of reflection
- Apply an evidence-based decision making approach, identifying elements which frame and drive decision making for problems in the sciences, social sciences, health, humanities and the fine arts including pre-professional education.
- Analyze the operation of complex systems using evidence and analysis of systems.
- Analyze ethics issues which are inherent in research and the use of evidence.
- Synthesize evidence to formulate responses to complex problems and/or make recommendations for new approaches to disciplinary and interdisciplinary issues and problems.
STIRS Framework, with Enduring Understandings\(^1\) and Keywords\(^2\)

**STIRS Component One: Evidence what it is and how it is used**

*Definition and uses of evidence across the disciplines*

**Enduring Understandings**

1. **Reductionist approaches to use of evidence**

   Evidence is built on information and forms the basis for supporting a conclusion. Evidence is defined, obtained, and used in a wide range of disciplines in the sciences, social sciences, health, humanities and the fine arts. Methods for obtaining and using evidence may be divided into one factor at a time or reductionist approaches and integrative approaches or systems thinking. Reductionist approaches aim to simplify by creating study and control groups that are as similar as possible except for the factor under investigation. Reductionist approaches begin with hypothesis generation which may result from inductive or deductive logic. Reductionist approaches aim at explanation or establishing the existence of cause and effect relationships such as whether an intervention has efficacy.

2. **Integrative approaches to the use of evidence**

   Integrative approaches often build upon reductionist approaches. They draw from multiple disciplines incorporating multiple influences or determinants of outcomes; look for interactions between factors; and use evidence-based approaches to understand and propose strategies for addressing complex problems. Integrative approaches aim to model the multiple influences or determinants of a single outcome rather than test a hypothesis. In doing this they view outcomes as the results of complex interacting systems. Reflecting on complex systems and questions before problems are posed and solutions considered is a key skill for integrative approaches.

3. **Theories and paradigm shifts**

   Both reductionist and integrative approaches are grounded in theories that attempt to explain fundamental relationships in the material and social worlds. Theories need to enable hypothesis testing which aims to refute the theory. Phenomena that cannot be explained by current theories often lay the groundwork for new theories that challenge the existing paradigm and lead to infrequent but immensely important paradigm shifts.

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\(^1\) Enduring understandings are statements summarizing important ideas and processes that have lasting value beyond the particular course or learning experience. They synthesize what students should take away from study in a particular content area and reflect potential pathways along which students can integrate knowledge and skills across the curriculum and beyond their undergraduate education.

\(^2\) Key words are underlined in the text and defined as part of this document. They represent important concepts which can be used as the basis for further explanation of the framework as well as for linking case studies or other applications to the framework.
4. Uses and display of evidence
Evidence can be used to achieve a range of important goals including problem description or question framing, generation of hypotheses, demonstration of etiology and efficacy, measurement of harms and benefits in applied settings i.e. net-effectiveness, evaluation of interventions, and prediction of future outcomes. Disciplines may focus on a limited number of these goals. Evidence-based problem solving aims to define one or more options with net-effectiveness for addressing a defined problem. Evidence-based decision making aims to provide methods for deciding between available options. Data-based reasoning requires an understanding of the relationships between the ways that information is presented and interpreted. Understanding how the visual display of data can effectively summarize large quantities of evidence as well as misrepresent evidence is fundamental to evidence-based problem solving and to integrating evidence into decision making.

5. Roles of statistical reasoning
Statistical significance testing uses data from study sample(s) to draw conclusions or inferences about larger populations. Statistical inference may be expressed as P-values or derived from 95% confidence intervals. Inherent in statistical significance testing are Type I and Type II errors. The strength of the relationship can be expressed in a number of ways including differences, proportions, and rates. The strength of the relationship or estimation needs to be distinguished from statistically significant. Adjustment for potential confounding variables is often needed before the investigator can draw conclusions about the existence of an association between a particular independent variable with the outcome or dependent variable. Multiple variable adjustment using multiple regression procedures allows the investigator to simultaneously take into account a large number of potential confounding variables.

6. Roles of analytical, intuitive, and logical reasoning
Analytical reasoning requires understanding the structure of relationships and drawing conclusions based on that structure. Analytical reasoning includes historical and interpretive methods as used in the humanities and fine arts. Logic models display the expected sequence of events and underlying assumptions which must be fulfilled to successfully achieve an intended outcome. Analytical frameworks plus logic models provide a coherent approach to evaluating potential interventions and drawing interpretations. Reasoning by analogy, determining how additional evidence affects an argument, applying principles or rules, and identifying flaws in arguments are all key skills in analytical reasoning.

Intuitive thinking utilizes information from multiple sources and senses and may produce outcomes without the user being able to identify the process used. Intuitive thinking based on experience is widely used and its strengths and limitation need to be understood. Intuitive thinking may also produce unique outcomes not based on experience which may contribute insights in the sciences, social sciences, health, humanities, and fine arts. It is important to appreciate the unique role of intuitive thinking in the humanities and fine arts. Disciplines have discipline-specific approaches to combining analytical, logical, and intuitive reasoning. An introduction to discipline-specific approaches and methods can provide an understanding of the
thought processes and skills required for pursuing expertise in a discipline and may help students determine the fit of the discipline with their own talents and interests.

**STIRS Component Two: Research Methods-Obtaining and ensuring the quality of the evidence**

*Where the evidence comes from and how its quality can be ensured*

**Enduring Understandings**

1. **Research methods**

   Qualitative and quantitative evidence provide complementary methods for collection and use of evidence. Unique methods exist for obtaining and using evidence in the humanities and fine arts including reflection which is often critical for interpreting and creatively responding to problems. Qualitative evidence may provide the basis for generating hypotheses, exploring mechanism underlying observed outcomes, better understanding the interactions between influences which produce an outcome, exploring the factors which produce change as the basis for prediction, as well as understanding the basis for differing interpretations etc.

   Quantitative study designs may be described as experimental or observational. In experimental designs the investigator intervenes to change the conditions and compares the outcomes in the intervention or study group to outcomes in the control or comparison group without the intervention. In observational studies the investigator observes the occurrence of events without intervening. Prior to beginning a quantitative investigation a study hypothesis needs to be defined. A study population defined by inclusion and exclusion criteria is also required. A sample size with adequate statistical power also needs to be estimated prior to beginning the investigation.

2. **Assignment to groups and assessment of outcomes**

   Assignment to study and control groups in research studies may utilize randomization that is, assignment using a chance process. Assignment to groups may be observed without the intervention of the investigator. Differences between the groups which affect outcomes i.e. potential confounding variables may occur by chance or due to the assignment process. Pairing may also be used to prevent confounding variables and allow comparisons between individual(s) or situations.

   Assessment of outcome needs to address the question being investigated. It needs to measure what it intends to measure which requires accurate, precise, and complete data collection. When surrogate or substitute measures are used they need to be strongly correlated with primary outcome of interest. Assignment and assessment are ideally masked so that neither the participants nor the investigators are aware of the group assignment when making the assessment of outcome.

3. **Analysis of results**

   Estimation or measurement of the strength of a relationship or the size of a difference; inference or statistical significance; and adjustment for potential confounding variables are all expected components of the analysis of results in quantitative research. To accomplish these analyses, data must be categorized or placed into categories which may be classified as continuous, ordinal, or nominal data. The type(s) of categories used determine the amount of data which is incorporated into the analysis and the type of methods which are needed to
analyze the data. Analysis should be conducted based on one primary outcome. If multiple outcomes representing multiple hypotheses are included in the analysis, the impact of these multiple comparisons needs to be taken into account when determining whether the results are statistically significant.

4. Interpretation-Criteria for cause and effect

Interpretation addresses conclusions for the situation or individuals included in the investigation such as whether a cause and effect or contributory cause exists. Observational studies are potentially capable of establishing the first requirement of contributory cause: (a) there is an association between the independent and the dependent variable at the individual level and the second requirement: (b) the "cause" precedes the "effect". Experimental interventions are often required to definitively establish the third requirement, namely (c) altering the "cause" alters the "effect". Contributory cause needs to be distinguished from necessary cause in which the presence of a "cause" is required to bring about an "effect" and sufficient "cause" in which the presence of a "cause" is all that is needed to bring about an "effect."

Often supportive or ancillary criteria need to be utilized to draw interpretations about cause and effect or efficacy. These supportive criteria include the strength of the relationship, dose-response relationship, consistency, and the biological plausibility of findings. Interpretation also includes examination of the impact of interventions on subgroups within a population. Subgroup analysis may include examination of the impact of interventions based on age, gender, race, socioeconomic status etc. An investigation should examine a limited number of subgroups defined prior to collecting the data.

5. Extrapolation

Applying research to new situations or to a new population or context requires making assumptions. This process is called extrapolation or generalizability. Extrapolations to similar situations require the fewest assumptions and can be made using data from the investigation. Extrapolations that extend the use of the intervention to new situations or to new populations need to explicitly state the assumptions being made in performing the extrapolation. Prediction of individual and future outcomes is a form of extrapolation which is extremely difficult requiring large numbers of assumptions. A broad concept of extrapolation includes reflection or "looking back" as well as "drawing out" or carefully extending beyond the evidence.

6. Ethical principles for research

Research needs to be conducted based on ethical research principles including the principles of respect for persons, beneficence, and justice. Planning and implementation of research aims to maximize the benefits and minimize the harms to the participants. This requires prior review of research proposals by an objective external body, high quality research designs, informed consent for human interventional research as well as an expanding set of safeguards to ensure ethical implementation. Ethical standards for animal and laboratory research also need to be established and maintained.

**STIRS Component Three: Evidence-based Problem Solving**
Using evidence to define and solve problems

Enduring Understandings

1. Approaches to evidence-based problem solving utilize both reductionist and integrative methods as well as evidence derived using qualitative and quantitative methods. Evidence-based problem solving often includes five steps: a) Problem identification and characterization; b) investigation of its etiology or causation and/or efficacy of potential interventions; c) development of evidence-based recommendations for potential interventions; d) examination of options for implementation of the interventions; and e) evaluation of the results of the intervention.

2. Problem framing and description- Framing the problem to solve requires evidence. Discipline-specific evidence is often needed including unique methods applicable to the humanities and fine arts. The time course of the problem, the burden of the problem, and often the financial costs are central to describing many problems. Describing the problem may provide a framework for integrating available qualitative and quantitative evidence to define what is known. It may also assist in developing a strategy for producing additional needed evidence. Evidence that describes the problem may be used to generate hypotheses.

3. Etiology/ efficacy and evidence-based recommendations

Evidence is needed to address the benefits and harms of potential interventions based on high quality study designs that address the definitive and/or ancillary criteria for cause and effect. The quality of the evidence plus the magnitude of the impact, including potential harms as well as the potential benefits, need to be incorporated into evidence-based recommendations. Evidence-based recommendations need to include a category for insufficient evidence indicating that recommendations cannot be made either for or against adoption of an intervention. Evidence-based recommendations should indicate the process of developing the recommendations including the process and timing for updating the recommendations. Evidence-based recommendations are not limited to cause and effect questions and may relate to conclusions based on interpretation and evaluation of alternative interpretations.

4. Implementation and evaluation

Evidence-based recommendations need to be implemented and the outcomes evaluated. Implementation often requires considering when, who, and how to implement an intervention. That is, at what stage in the development of the problem, aimed at which groups or populations, and using what type(s) of methods. Evaluation needs to address the observed benefits and harms of the implemented intervention(s) as well as the potential population impact or reach of the intervention including its potential for sustained implementation in practice. Comparing net-effectiveness between potential interventions and including costs in the evaluation are desirable features of evaluation.

5. Methods of evidence-based problem solving-data synthesis and translational research

Data synthesis integrates existing research to derive new understandings that go beyond the conclusions from one particular investigation. Systematic reviews aim to address a wide range of
relevant questions identifying the issues which are resolved and those requiring additional investigation. Meta-analysis is a quantitative method for combining investigations which address the same basic study question. Translational research provides a framework for connecting the roles of different types of research from basic innovations, to efficacy, to net-effectiveness, to population impact.

**STIRS Component Four: Evidence-Based Decision Making**

*Using evidence to define options and make decisions*

**Enduring Understandings**

1. *Heuristics and decision rules* Heuristics or rules of thumb often govern human decision making due to humans' limited ability to process large quantities of data. Heuristics are an essential part of everyday decision making but are prone to a range of analytical and logical limitations. Decision rules, such as maximizing expected utility and satisficing, provide an objective basis for combining harms and benefits and selecting between options as part of evidence-based decision making. Unique methods are used in the humanities and fine arts to describe and challenge conventional approaches to decision making including understanding a text or historical event differently, which adds to the understanding.

2. *Comparing benefits and harms* Evidence-based decision making is often conducted based on maximizing expected utility. This requires taking into account the probabilities of desirable and undesirable outcome(s), utilities or the importance placed on the outcome(s), and the timing of the outcome(s). Additional elements that need to be considered in decision making include attitudes toward risk including risk-taking and risk-avoiding attitudes and the reference point being used. The process required to implement the intervention may greatly impact decision making. At times financial costs may be a factor when comparing benefits and harms. Decision analysis and cost effectiveness analysis can be useful tools to structure the decision making process.

3. *Principles of testing* Testing is used in a wide range of disciplines as the basis for making decision at the level of the individual, population, or system. It is important to recognize that testing is rarely perfect and results in both false negative and false positives. Defining false negative and false positive results requires a definitive or gold standard test. Applying testing requires estimation of the pretest probability of the condition. The information provided by the test may be measured using the sensitivity and specificity of the test. The probability of the condition after the results of a test are known is called the predictive value of a positive test and the predictive value of the negative test. Combining tests to make decisions is prone to error unless the tests used have different false positive and false negatives.

4. *Prediction and prediction rules* Predictions of future events or the outcomes at the individual, population or systems level is extremely difficult. Prediction rules incorporate the factors observed to be associated with an outcome in the past, the strength of the association, and the interactions between these factors. Prediction rules may take the form of complicated models
describing a system. Prediction rules may be used as the basis for individual, group, and systems level decisions. Prediction requires accurate and complete information on the factors affecting outcome based on past observation of these factors. Prediction also assumes that past relationship will continue into the future.

5. Systems analysis

A systems analysis approach models the factors which influence outcomes, the strength of these factors and their interactions as well as their changes over time. Systems analysis can be incorporated into evidence-based decision making. Systems approaches help in recognizing bottlenecks that impede positive outcomes and leverage points that provide opportunities to catalyze improved outcomes.

6. Ethical principles for decision making

Evidence-based decision making needs to recognize and utilize ethical principles. These principles may address the goals of decision making which may range from maximizing overall group benefit to distributional justice or minimizing harm to vulnerable groups of individuals. Ethics issues also bear on the process of decision making including balancing the rights and responsibilities of individuals, stakeholders, and society as a whole.
**STIRS Framework-Key Words** - In order of their occurrence in the STIRS framework

**Evidence** - Information which support a conclusion. Evidence may be derived from research investigations, observations, or other methods and submitted for careful review with an opportunity to challenge the evidence.

**Information** - Data is raw unorganized measurement. When data are processed, organized, structured, or presented in a given context so as to make it useful for a particular purpose, it is called information.

**Reductionist approach** - An approach to obtaining evidence that looks at one factor or variable at a time while controlling for or taking into account other factors or variables.

**Study and control groups** - A study group is made up of participants or objects which have the factor under investigation or are exposed to the factor being investigated. Control or comparison groups in contrast do not have the factor under investigation or are not exposed to the factor being investigated.

**Hypothesis** - A hypothesis is a relationship between factors or variables. An hypothesis should be a proposed explanation for a phenomenon which leads to conclusion(s) which can be tested as part of an investigation. The ability to test the hypothesis in an investigation is key to its role in the reductionist approach.

**Inductive logic** - Inductive logic starts with observations and develops hypotheses for testing based on these observations. That is, inductive logic goes from the specific to the general.

**Deductive logic** - Deductive logic starts with accepted generalizations or theories and develops a hypothesis about a specific situation. That is, deductive reasoning goes from the general to the specific.

**Intervention** - A general term encompassing a wide range of human action aimed at improving outcome.

**Efficacy** - The extent to which an intervention produces a beneficial effect when assessed under the ideal conditions of an investigation.

**Integrative approach** - Obtaining evidence by examining multiple factors or variables at the same time and examining their influence on outcomes as well as the interactions that occur between factors.

**Multiple influence or determinants** - Influences or determinants are factors, often occurring long before the outcome, which eventually affect the probability of an outcome. The terms influences and determinants are often used with an integrative approach and have been referred to as the "causes of causes".

**Interactions** - Interaction occurs when the probability of an outcome resulting from the presence of one variable is altered by the level of a second variable. Interaction implies that the probability of an outcome is either less than or more than expected from adding together the impacts of each factor. (Synonym: effect modification)

**System** - A group of parts combined to form a whole that functions as a unit.

**Theories** - A set of statements or principles devised to explain a group of facts which have been repeatedly tested or are widely accepted and can be used to provide explanations or make predictions about the occurrence of outcomes or phenomena.

**Paradigm shift** - A paradigm is a broad intellectual framework or theory used to analyze a disciplinary issue. Paradigm shifts may result in a new framework or theory that is developed when current frameworks or theories do not adequately explain phenomenon or outcomes which they are intended to explain or predict.

**Net-effectiveness** - A measure of outcome that reflects the benefits minus the harms.

**Visual display of data** - A term which refers to a large and growing number of methods for presenting data in visual formats e.g. charts and graphics, geographic information systems.

**Statistical significance testing** - A statistical technique for determining the probability that the data observed in a sample, or more extreme data, would occur by chance if there is no true difference or association in the larger population (i.e., if the null hypothesis of no association or difference is true). (Synonym: inference, hypothesis testing)
**Sample** - A subset of a population obtained in order to draw conclusions or inference about the larger population from which the subset is obtained.

**Population** - A large group, not necessarily made up of individuals, which includes all the units which define the universe of interest e.g. all residents of a state, all high schools in the country.

**P-value** - In statistics the P-value is the probability of obtaining the observed data, or more extreme data if the null hypothesis is true.

**95% Confidence intervals** - In statistical terms, the interval of numerical values within which one can be 95% confident that the value in the larger population lies. (Synonym: interval estimate)

**Type I Error** - An error that occurs when data demonstrate a statistically significant result when no true association or difference exists in the larger population.

**Type II Error** - An error that occurs when the sample’s observations fail to demonstrate statistical significance even though a true association or difference actually exists in the larger population.

**Differences** - A measurement obtained by subtracting one measurement from another measurement

**Proportion** - A measurement which includes a numerator and a denominator that is a ratio, in which the numerator is a subset of the denominator. Prevalence is a proportion which measures the probability that a condition is present at one point in time.

**Rates** - A measurement which includes a numerator and a denominator in which the numerator is a subset of the denominator and there is also a time interval over which the numerator is measured. Incidence is the rate at which new conditions develop.

**Estimation** - A measurement of the strength of an association or the magnitude of a difference between an independent and a dependent variable e.g. correlation coefficients, odds ratios, relative risks etc.

**Adjustment** - Statistical methods used after the collection of data to take into account or control for the effect of known or potential confounding variables and interactions.

**Confounding** - A factor or variable that is different in the study group compared to the control group and the factor affects the outcome being assessed. Excludes factors included in the chain of causation.

**Association** - An association is present when the presence of a factor represented by an independent variable occur along with an outcome represented by a dependent variable more often than expected by chance alone i.e. a statistically significant relationship. Correlation may be used as a synonym for association or may imply a special type of association in which both the independent and dependent variable are measured using continuous data.

**Independent variable** - A factor or variable being measured to explain or predict the occurrence of a dependent variable.

**Dependent variable** - An outcome or endpoint which is measured for participants in the study and in the control group.

**Multiple regression** - A statistical method that allows simultaneous adjustment for a large number of potential confounding variable and interactions.

**Analytical reasoning** - The ability to understand the structure of relationships and to draw logical conclusions about that structure. Requires the ability to reason deductively from a set of statements and rules or principles that describe relationships among persons, things, or events.

**Logic models** - A graphical or descriptive representation of cause and effect relationships between components of an intervention or program.

**Intuitive thinking** - Intuition is receiving input and ideas without knowing exactly how and where they came from. It utilizes multiple senses and thought processes to produce conventional as well as unconventional results.

**Qualitative evidence** - Investigations which use methods such as listening or observing to gather and organize data into patterns or themes.

**Quantitative evidence** - Investigations in which numbers are used to measure variables such as characteristics, concepts, or objects.
Experimental design- An interventional investigation using study and control groups which aims to ensure, often using randomization, that the study and control groups are similar or identical except for the factor being investigated.

Observational design- An investigation using study and control groups comparing participants with and without a factor by observing the occurrence of events rather than intervening. Observational studies may begin with study and control groups with and without a possible risk factor in a cohort study. They may also begin with study and control groups with and without a condition in a case-control study. Cross-sectional studies, in which the factor and the outcome are measured at the same point in time, measure the prevalence rather than the incidence limiting their contribution to studying etiology.

Inclusion and exclusion criteria- Defining a study population for an investigation requires delineating characteristics which permit acceptance of participants and prohibit acceptance of participants into an investigation.

Statistical power- The probability of demonstrating statistical significance in a subsequent investigation based on a proposed sample size assuming a difference or association of a defined size is present in the larger population. Statistical power equals (1-Type 2 error).

Assignment- The process by which participants become part of a study or a control group. Assignment may occur by observation or by randomization.

Randomization- A method of assignment in which individuals or groups have a known, but not necessarily equal, probability of being assigned using a chance process to a particular study group or control group. (Synonym: random assignment)

Pairing - A method for assignment in which similar participants in a study group and in a control group are treated as a unit and their outcomes are compared to each other and analyzed as a unit.

Assessment of outcome- The process by which the outcome or endpoint of an investigation is measured for participants in the study and also in the control groups.

Surrogate outcome- An outcome measurement which substitutes for the measurement of interest such as substitution of a test result for measurement of a clinically or socially important outcome.

Primary outcome- An outcome which is used as the basis for calculating the required sample size for an investigation and therefore is expected to be statistically significant if a difference or association is present in the larger population.

Masked- A participant in an investigation and the investigator(s) ideally are not aware of their group assignment when assessing the outcome. (Synonym: blinded)

Accurate- On average the results approximate those of the phenomenon under study. Without systematic error or bias in either direction

Precise- Without variability from measurement to measurement of the same phenomenon. Without random or chance error. (Synonyms: reproducibility, reliability)

Complete- An investigation is complete if all participants included in study and control groups are included in the measurement of outcome and the measurements of outcome are made with equal intensity.

Continuous data- Data which is measured on a scale with an unlimited number of equally spaced potential values or categories e.g. blood pressure or IQ.

Ordinal data- Data which is measured on a scale with a limited number of potential values or categories which have an inherent ordering from lowest to highest but the distance between the categories is not known or is not equal e.g. stages or cancer, stages of intellectual development

Nominal data- Data with a limited number of named categories which cannot be ordered e.g. race, hair color or with only two categories i.e. dichotomous e.g. dead/ alive, pass test/ fail test.

Multiple comparisons- When more than one outcome reflecting more than one hypothesis is examined, the investigator needs to take into account these multiple comparisons when determining whether the
results are statistically significant. Lowering the $P$-value required to establish statistical significance is one method for taking into account multiple comparisons.

**Interpretation** - Drawing conclusions for participants or situations included in an investigation.

**Contributory cause** - A definition of cause and effect which implies that three definitive criteria for contribute cause have been established i.e. an association exists between an independent and a dependent variable, the "cause" precedes the "effect", and "altering the "cause" alters the "effect". "Communicable conditions use association, isolation, and transmission as a parallel set of criteria to establish contributory cause.

**Supportive criteria** - Criteria used to provide additional support for the existence of a contributory cause when the definitive criteria cannot be established. Supportive criteria commonly used to make evidence-based judgments include strength of the relationship, dose-response relationship, consistency, and the biological plausibility of findings. (Synonym: ancillary criteria)

**Subgroup analysis** - An examination of smaller groups within a population defined by characteristics such as age, gender, race, socioeconomic status etc. Subgroups should be defined prior to collecting the data rather than after the overall results are known i.e. pre-hoc rather than post hoc.

**Extrapolation** - Drawing conclusions for participants or situations not included in an investigation (Synonyms: generalizability).

**Prediction** - A special form of extrapolation in which the investigator extrapolates to a future point in time. May also refer to efforts to develop a prognosis or predict outcome for one particular individual.

**Ethical research principles** - Conduct of research under internationally accepted principles designed for the protection of participants. These principles include respect for persons, beneficence, and justice.

**Informed consent** - Method used in human research which aims to ensure that participants in an investigation choose to participate or not participate based on adequate information on the potential benefits and harms of participation as well an understanding of the process that will occur.

**Evidence-based problem solving** - An approach to presenting problems and identifying and evaluating their etiology as well as potential interventions to improve outcome which relies to the extent possible on data from research investigations.

**Benefits** - The desirable outcomes which result from an intervention.

**Harms** - The undesirable or adverse outcomes which result from an intervention. Harms are often referred to as risks. Technically, however, risk is a measure of the probability of an outcome either a benefit or a harm. Use of the term risk as a synonym for harm can cause confusion.

**Systematic reviews** - A systematic review is a critical assessment and evaluation of all available evidence including qualitative evidence that address a broadly defined issue. The investigators use a defined method of locating, presenting, and evaluating all available published and unpublished literature.

**Meta-analysis** - A series of quantitative method for potentially combining data from multiple research investigations which may allow investigators to draw conclusions which could not be obtained based on the data from any one of the investigations.

**Translational research** - A framework for connecting multiple types of research from basic or laboratory research to their use in improving individual and population outcomes.

**Heuristics or rules of thumb** - Methods used in non-quantitative or subjective decision-making that use only a portion of the potentially available data and thus simplifies the decision-making process.

**Decision rules** - A set of criteria often expressed as a formulae which is used to make a choice between different alternatives.

**Maximizing expected utility** - A decision rule in which the option with the greatest expect utility is selected. Expected utility incorporates measures of probability, utility, and timing.

**Satisficing** - A decision rule often used when complete data on the options is not available at the time of the decision. Satisficing implies selecting a good enough solution that satisfies the most important desired outcomes.
Utilities - A measurement of the value or importance placed on a particular outcome using a scale of 0 to 1 with 0 indicating immediate death and 1 equaling full health or wellbeing. Using this scale allows utilities to be multiplied by probabilities which are measured on same 0 to 1 scale.

Timing of the outcome(s) - The timing of occurrence of potential benefits and potential harms relative to the timing of the intervention. Outcomes which occur in the future need to be discounted or adjusted to take into account the timing of their occurrence.

Risk - A risk or chance is an option in which there is more than one possible outcome. When the probability of an outcome is 1 i.e. 100% or 0 i.e. 0% there is only one possible outcome. That is, the outcome is certain. When the outcome is certain a decision maker is not taking a risk or chance.

Risk-taking - Risk-taking can be defined as selecting an option which incorporates risk and has a lower expected utility rather than an option with a certain outcome and a higher expected utility.

Risk avoiding - Risk-avoiding is defined as selecting an option which includes a certain outcome and a lower expected utility rather than an option which incorporates risk but has a higher expected utility.

Reference point - Benefits and harms are often judged compared to a reference point. Reference points may be the current status quo but they often utilize past states of wellbeing. The choice of reference point can determine whether an outcome is viewed as a loss or a gain.

Decision analysis - A description of the decision options, the probability of specific outcomes, as well as the benefits and harms of each outcome. May be displayed and summarized as a decision tree.

Cost-effectiveness analysis - A type of decision analysis in which financial costs are included as well as the non-financial benefits and harms.

False negative - An individual whose results on a test are negative but who actually has the condition as determined by the definitive or gold standard.

False positives - An individual whose results on a test are positive but who actually does not have the condition as determined by the definitive or gold standard.

Gold standard test - The criteria used to unequivocally define the presence and absence of a condition. (Synonym: reference standard)

Sensitivity - The proportion of those with the condition, as measured by the gold standards, who have positive results on a test being investigated.

Specificity - The proportion of those without the condition, as measured by the gold standards, who have negative results on a test being investigated.

Predictive value of a positive test - The proportion of individuals with a positive test who actually have the condition as measured by the gold standard.

Predictive value of a negative test - The proportion of individuals with a negative test who actually do not have the condition as measured by the gold standard.

Systems analysis - A structured effort to understand the influences of multiple factors and their interactions on outcomes and how one intervention may influence other interventions or outcomes.

Bottlenecks - A bottleneck occurs in a system when there are barriers to implementation of an intervention which slow down or reduce the benefit or increase the harm of the intervention.

Leverage points - A leverage point occurs in a system when location(s) for intervention(s) are identified which produce large improvements in outcome.

Maximizing overall group benefit - Selecting an option which maximizes the benefits minus the harms for the group or population as a whole. Doing the greatest good for the greatest number.

Distributional justice - Giving consideration or special importance to subgroup(s) which disproportionately experience the harms of an intervention. Unique vulnerabilities or social inequities may be justification for giving special consideration or importance to a particular subgroup.