C. Applying Research to Clinical Practice

1. Assessment of study design, performance & analysis (internal validity)
   a. Recognize when appropriate control groups have been selected for a case-control study
      - Free of the outcome of interest
      - Representative of the population at risk of the outcome (e.g. women undergoing laparoscopy are unlikely to be representative of all women at risk for developing endometriosis)
      - Selected independent of the exposure of interest (e.g. NSAID use is likely to be overrepresented in controls selected from rheumatology service)
   b. Recognize when appropriate control groups have been selected for a cohort study
      - The unexposed comparison group should be as similar as possible with respect to other factors that could influence the outcome being studied (possible confounding factors).
      - The comparison group may be the general population from which the cohort is drawn, or it may be another cohort of persons thought to have had little or no exposure to the substance under investigation, but otherwise similar
      - Information collection should be as accurate and as comparable as possible in all groups in order to avoid biasing the association.
   c. Recognize the use and limitations of surrogate endpoints
      - Biomarker (lab measurement or physical sign) intended to substitute for a primary clinical endpoint
      - May be used when the primary endpoint is undesirable or when the number of events is very small, thus making it impractical to conduct a clinical trial to gather a statistically significant number of endpoints.
      - Should correlate with the frequency of the clinical end point both as an epidemiologic marker and as a therapeutic responder.
      - Advantages:
        a. Demonstration of effect may be done more quickly and require a smaller trial
        b. May demonstrate mechanistic relationship between intervention and endpoint of interest
      - Disadvantages:
        a. Assumes that the measured effect represents the clinically meaningful endpoint being investigated
        b. May not provide information about off-target effects or health benefits that involve other mechanisms
   d. Understand the use of intent-to-treat analysis
      - Study participants are analyzed according to the groups in which they were randomized, even if they did not receive or comply with treatment
      - Contrasts with "as treated" analysis in which subjects are analyzed according to the actual treatment they received
      - Advantages:
a. Preserves the benefits of randomization, thus ensuring that analysis accounts for unmeasured confounders
b. Better accounts for factors that can influence the outcomes of prescribed treatment (e.g. poor compliance or drop-out due to serious side effects)
- Disadvantages:
  a. Lacks optimal methods to account for participants who were lost to follow-up

e. Understand how sample size affects the power of a study
  - Power is the probability of finding a statistically significant result when it exists (avoiding type 2 error)
  - An increased sample size increases the statistical power of a study.
  - Power analysis can be used to calculate the minimum sample size required to accept the outcome of a statistical test with a particular level of confidence.

f. Understand how sample size may limit the ability to detect adverse events
  - Serious adverse events are rare and may not be detected within the sample size of the study population of a Phase III trial
  - Rule of three: if a certain event did not occur in a sample with \( n \) subjects, the interval from 0 to \( 3/n \) is a 95% confidence interval for the rate of occurrences in the population (if no adverse event is reported in 1500 subjects, we can conclude with 95% confidence that an adverse event will occur in <0.002 subjects).

g. Understand how to calculate an adequate sample size for a controlled trial (eg, clinically meaningful difference, variability in measurement, choice of alpha and beta)
  - Sample size calculation is used to determine the number of participants needed to detect a clinically relevant treatment effect. It includes the following components:
    a. Type I error (alpha): chance of falsely rejecting the null hypothesis (false-positive), most commonly set at 0.05
    b. Type II error (beta): chance of falsely accepting the null hypothesis (false negative), commonly set at 0.2
      - power = 1 - beta
      - larger sample sizes result in smaller beta and increase in statistical power
    c. Clinically meaningful difference: minimal difference between the studied groups that the investigator considers biologically plausible and clinically relevant
      - If the difference between two treatments is small, a larger sample size will be required to detect a difference
      - Sample size is inversely proportional to the square of the difference
    d. Variability: the variance of the outcome measure, expressed at the SD in case of a continuous outcome; the higher the variance the larger the sample size needed to demonstrate a difference

2. Assessment of generalizability (external validity)
   a. Identify factors that contribute to or jeopardize generalizability
External validity is the extent to which results of a study on one sample population can be generalized to other populations and settings. Factors that may influence external validity include:

- Aptitude-treatment interaction: individuals differ in their readiness to benefit from a particular treatment at a particular time
- Situation: all situational specifics (e.g. treatment conditions, timing, location, treatment administration, investigator, scope and extent of measurement, etc.) of a study potentially limit generalizability.
- Carry-over effects: increased post-test performance due to previous exposure to experiment through pre-test or decreased performance due to experimental fatigue
- Reactivity: occurs when participant behavior in a study is different from the way they would normally behave, because they know they are being studied
- Rosenthal effects: higher expectations may lead to increased performance

b. Understand how non-representative samples can bias results

- Sampling bias: systematic error due to a non-random sample of a population, causing some members of a population to be less likely to be included than others

c. Assess how the data source (e.g., diaries, billing data, discharge diagnostic code) may affect study results

- Information bias: occurs when key study variables (exposure, outcomes) are inaccurately measured or classified; may result from poor interviewing techniques or differing levels of recall by participants

3. Application of information for patient care

a. Estimate the post-test probability of a disease, given the pretest probability of the disease and the likelihood ratio for the test

\[
\text{Pretest odds} = \frac{\text{Pretest probability}}{(1 - \text{Pretest probability})}
\]

\[
\text{Posttest odds} = \text{Pretest odds} \times LR = \frac{\text{Posttest probability}}{(1 - \text{Posttest probability})}
\]

\[
\text{Posttest probability} = \frac{\text{Posttest odds}}{(\text{Posttest odds} + 1)}
\]

Posttest probability may also be estimated using the Fagan Normogram:
b. Calculate absolute risk reduction
   - ARR = CER – EER
   - CER = control group event rate (proportion of patients with observed event in control/placebo group)
   - ERR = experimental event rate (proportion of patients with observed event in experimental/study drug group)
   - ARR > 0 if the risk of adverse event is decreased in experimental group
   - ARR < 0 if the risk of adverse event is increased in experimental group

c. Calculate and interpret the number-needed-to-treat
   - Number needed to treat (NNT) is the number of patients who need to receive an intervention in order to prevent one additional adverse outcome
   - NNT = 1/ARR
   - The smaller the NNT, the more effective the treatment

d. Distinguish statistical significance from clinical importance
   - Statistical significance means that a result is unlikely to occur by chance alone
   - Clinical importance refers to the magnitude of the effect (Is the difference between the study drug and the standard of care large enough to justify altering your practice?)

4. Using the medical literature
a. Given the need for specific clinical information, identify a clear, structured, searchable clinical question
   Components of a searchable clinical question: PICO
   - Patient/Population: may include age, sex, ethnicity, socioeconomic status, disease
   - Intervention: therapeutic measure, medication, diagnostic test
   - Comparison/Control: another intervention, placebo, standard of care, diagnostic gold standard
   - Outcome: desired outcome should be measureable

b. Identify the study design most likely to yield valid information about the accuracy of a diagnostic test
   - Cross-sectional study that compares a test’s classification of a diagnosis with a reference standard’s classification in a relevant study population
   - Generates data that can be used to calculate the sensitivity, specificity, PPV, NPV, and likelihood ratios for the diagnostic test

c. Identify the study design most likely to yield valid information about the benefits and/or harms of an intervention
   - Randomized controlled trial provides the strongest evidence of the clinical efficacy/harm of an intervention compared to a placebo or standard of care in the clinical setting

d. Identify the study design most likely to yield valid information about the prognosis of a condition
Cohort study: patients with a disease of interest are identified, followed forward in time, and their outcomes measured. The goal is to identify prognostic factors associated with specific outcomes.

D. Principles of Teaching and Learning
1. Educational theory
   a. Understand the basic principles of adult learning theory:
      - Self-directed learning: process by which individuals take the initiative to diagnose their learning needs, formulate learning goals, identify resources for learning, choose and implement appropriate learning strategies, and evaluate learning outcomes, with or without the assistance of others
      - Goal-oriented: content should be focused on solving problems rather than memorizing information
      - Past learning/life experience: learning should build on previous knowledge/experience
      - Internal motivation: while many children are driven by external motivators (grades, punishment), adults are driven by internal desire to learn

   b. Understand the attributes of an effective learning environment
      - Physical environment: formal environment (classroom) limits distractions whereas informal setting may facilitate active participation and group discussion
      - Interpersonal environment: approaches that respect the individual, drive out fear, and encourage teamwork enhance learning effectiveness
      - Organizational environment: use of cooperative groups and collegial teams encourages participation

   c. Understand the importance of "reflective practice" in teaching and learning
      - Reflective practice is the ability to reflect on one's actions so as to engage in a process of continuous learning. It involves a cyclic pattern of experience and the conscious application of lessons learned from experience
      - Important tool in practice-based professional learning settings where people learn from their own professional experiences, rather than from formal didactic learning.
      - Goals include:
        • Identification of personal and professional strengths and areas for improvement
        • Identification of educational needs
        • Further understanding of own beliefs, attitudes and values
        • Encouragement of self-motivation and self-directed learning
        • Improvements of personal and clinical confidence

   d. Identify strategies that motivate learners
      - Extrinsic motivation:
        • Learner assessment
        • Constructive feedback on performance
- **Intrinsic motivation:**
  - Identify learners’ needs to make earning more relevant and interesting
  - Encourage self-efficacy: attainment of new confidence in skills enhances motivation
  - Create a challenging but supportive and respectful learning environment
  - Actively engage learners: problem-based, practice-based, experiential, and cooperative learning

e. Recognize the impact of the "hidden curriculum" on learning
  - Unintended and often unrecognized transmission of behaviors, perspectives, and attitudes from mentors to trainees
  - Tends to be more memorable than formal teaching and plays a central role in development of professionalism
  - May conflict with professional values explicitly taught in the formal curriculum

2. Feedback and evaluation
   a. Identify components of effective feedback
      - Undertaken with the teacher and trainee working as allies, with common goals
      - Well-timed and expected; works best when solicited rather than imposed
      - Based on first-hand data
      - Deals with specific examples, not broad generalizations
      - Discusses objective observations of decisions and actions, rather than assumed intentions
      - Regulated in quantity and limited to behaviors that are remediable
      - Phrased in descriptive nonjudgmental language
   b. Distinguish between formative and summative feedback
      - Formative feedback provides students and teachers with information needed to improve the learning process while it is happening; provides a “low stakes” assessment with the goal of monitoring progress toward a goal or objective
      - Summative feedback is generally administered at the end of a unit or course with the goal of measuring the mastery of the learning objectives, usually yielding a grade
   c. Distinguish between evaluation and feedback
      - Feedback offers the learners insight into what went well and what could be improved during an observed interaction or activity with the goal of improving future performance in the same activity
      - Evaluation presents judgment about how well or poorly the student met a given goal, often in comparison to peers
   d. Understand the strengths and weaknesses of various methods to evaluate learners
      - Written exams:
        - Pros: relatively economical, familiar to students and teachers, anonymous
        - Cons: encourages surface learning, often tests memory more than understanding, does not provide feedback
- Oral exams:
  • Pros: good for isolating particular strengths or weaknesses, better at assessing depth of understanding
  • Cons: not anonymous, cannot test entire syllabus
- Essays:
  • Pros: allows for individual expression, tests breadth and depth of knowledge, tests written communication
  • Cons: cannot test entire syllabus, time consuming to grade, subjective evaluation
- Portfolios:
  • Pros: evidence of wide range of skills and attributes, demonstrate progress in learning
  • Cons: time consuming to assemble and evaluate, subjective evaluation
- Presentations:
  • Pros: students learn from own and others’ presentations, may be used in individual and group work
  • Cons: time consuming, not anonymous

3. Teaching methods
   a. Understand the strengths and weaknesses of various teaching methods:
      - Lecture:
        • Pros: useful for large groups, presents information in direct logical manner
        • Cons: Passive audience, learning difficult to gauge, experts not always good teachers
      - Small group discussion:
        • Pros: allows active participation, pools ideas and experiences from group, can reach group consensus
        • Cons: few participants can dominate, can get off track, time consuming
      - Bedside teaching:
        • Pros: allows demonstration of history taking, physical exam skills, communication with patients, and professional attitude
        • Cons: patient may not be available, potential burden to patient, limited audience size
      - Simulation:
        • Pros: allows practice of history taking, physical exam skills, communication with patients, and professional attitude with possibility of direct feedback
        • Cons: certain types of pathology are impossible to simulate genuinely

   b. Understand that individuals may learn more effectively with certain teaching methods (eg, reading, hearing, doing) than with others

4. Educational planning
   a. Understand the role of needs assessment in educational planning
- Systematic diagnostic process used to determine clinician learning needs before selection and delivery of education
- Identifies real or perceived gaps between current clinical competence and that which is desired or optimal
- May reflect educational interests or deficiencies of an individual or group

b. Distinguish between goals and learning objectives
- Goal: broad statement of expected learning outcome of a course or program
- Objective: concrete, specific statement of observable student behaviors that can be evaluated/measured at the conclusion of a learning activity and contributes to reaching the goal
- A goal has multiple learning objectives

c. Identify components of well-formulated learning objectives
- Behavior: describes the observable competency to be learned in performance terms
- Criterion: defines the level of proficiency that is expected (in terms of quality, quantity, and/or time measurements)
- Condition: addresses time, place, resources, and circumstances for performing the task
- Clear learning objectives should be specific, measurable, action-oriented, realistic, and time-bound

d. Recognize the strengths and weaknesses of various educational outcome measures (e.g., participant satisfaction, acquisition of knowledge and skills, behavioral change, patient outcomes)
- Participant satisfaction:
  - Pros: provides feedback on content and delivery, may be done electronically
  - Cons: may not reflect learning, retention, or change in performance
- Acquisition of knowledge and skills:
  - Pros: direct outcome of learning activity; assessment of immediate knowledge acquisition may be done via post-activity audience response or test
  - Cons: difficult to arrange observation and review of acquired skills or knowledge retention
- Behavioral change:
  - Pros: educational activities should be transformative; may be a planned, observed, or reported change
  - Cons: assessing behavior change is difficult and expensive
- Patient outcomes:
  - Quality improvement methodology can be used
  - Difficult to measure broad impact