Research and Biomedicine Concepts in eHealth

Foundational Curriculum:
Cluster 7: Patient and Device Integration/Research and Biomedicine
Module 13: Research, Biomedicine, and Device Development
Unit 1: Research and Biomedicine Concepts in eHealth
FC-C7M13U1

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Unit Objectives

- Describe eHealth research and state its importance
- Describe the research process, including citing resources, tracking work, and referencing or repeating the process if and when needed, using health IT/eHealth tools when available
- Convey the importance of developing precise and relevant questions for research
- Describe probability theory and the applicability of probability theory in IT supported health research to foster better patient care and robust outcomes

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Unit Objectives (cont'd)

- Identify various requestors, major sources, uses and users of health care data for research purposes
- Differentiate between primary and secondary research
- Name eight best practices in healthcare research techniques that utilize health IT/eHealth tools
- State the validation and verification principles for research data and information using health IT/eHealth
- Explain the basic principles in biomedicine
- Describe the use of eHealth in biomedicine

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eHealth in Research

- The term "health research," sometimes also called "medical research" or "clinical research," refers to research that is done to learn more about human health
- Health research also aims to find better ways to prevent and treat disease. Health research is an important way to help improve the care and treatment of people globally.
- **eHealth research** can be defined as the use of electronic and mobile health applications, information and communication technologies to assess, monitor, and improve health within a research context

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The Importance of eHealth in Research

- Extensive data can readily be collected using eHealth research
- Potential errors in eHealth research and health care can be reduced and/or avoided and the effectiveness of programs can be maximized by incorporating users' perspectives (how individuals interact with technologies and healthcare systems) into eHealth research and intervention design
- Finally, researchers can utilize electronic data to maximize and tailor behavioral interventions

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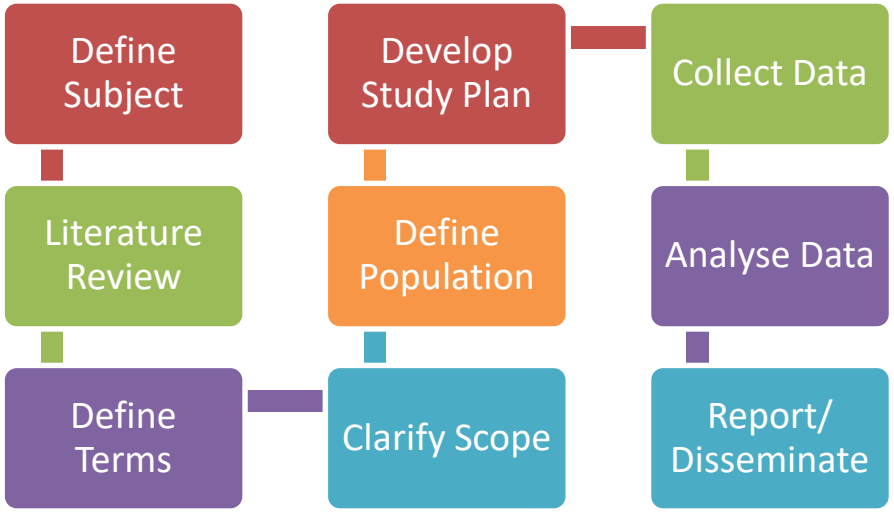
eHealth Research Process

Generally, health research will proceed according to the following process. Step order and specific step names may vary, depending on the subject matter and researcher. Steps are usually part of most formal healthcare research that involves eHealth, both basic and applied:

1. **Define Subject**
2. **Literature Review**
3. **Define Terms and Concepts**
4. **Clarify the Scope of the Study**
5. **Define the Study Population**
6. **Develop the Instrumentation Plan/Study Plan**
7. **Collect Data**
8. **Analyse/Interpret Data**
9. **Report and Disseminate Results**



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eHealth Research Process (cont'd)

1. *Define Subject - Subject area identification/formulation of the topic*: Consists of defining the subject area of one's interest and following that subject area to conduct subject related research. This can be done using various eHealth mechanisms.

2. *Literature Review/Hypothesis*: A review of the available literature is necessary to review information available about the subject area. Then, a testable prediction can be made which designates the relationship between two or more variables. A systematic review involves a literature review focused on a research question that tries to identify, appraise, select and synthesize all high quality research evidence. This step is simplified with eHealth tools, such as the Internet. Citing resources is an important part of this step.

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eHealth Research Process (cont'd)

3. *Define terms and concepts*: In this step, the details of the study, including terms and concepts, are laid out in a clear fashion so that they make sense to both researchers and study participants. eHealth can be used to disseminate the terms and concepts to all participants. Items that need to be considered include:
    a. Sampling
    b. Statistical issues
    c. Qualitative/Quantitative Research
    d. Collaborations
    e. Intellectual Property

4. *Clarify the scope of the study*: Specific details are developed in regards to defining the variables and how they will be measured/assessed in the study. These details can be compiled in an electronic specifications document.

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eHealth Research Process (cont'd)

5. *Define the study population:* The candidates for the members of the study are selected based on criteria determined in the literature review and scope clarification. Electronic consent forms can be obtained.
6. *Develop the Instrumentation Plan/Study Plan*: This step involves determining what data will be collected, how it will be represented to participants, and what the order and priority will be. It includes preparing samples, gathering information from or about these samples by using specific research instruments, and insuring instruments used for data collection are valid and reliable. eHealth can simplify this process.
7. *Collect data*: Involves actually studying the population according to the instrumentation/study plan, performing questionnaires, collecting lab data, dispensing medications and noting effects, etc. In this step, individual components of data are collected. EHRs and other eHealth applications can be used to collect data. Tracking data collected and work done is an important part of this step.

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eHealth Research Process (cont'd)

8. *Analyse/Interpret Data*: This step involves breaking down the individual pieces of data to draw conclusions about the information, either in components or as a whole. The analysis can be represented through tables, figures, or pictures, and then described in words. eHealth tools such as data analysis software and data warehouses can be used to analyse data. Retracing of steps may be necessary to validate results.
9. *Report and Disseminate:* It is important to remember to disseminate your findings outside of academia and to those who have participated or who may benefit from your research. This may be in the form of a research report, dissertation or thesis, lay summary, paper for publication, press release or poster presentation, etc.

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Relevant Questions To Develop Hypotheses for Research

- Relevant questions to develop hypotheses for research can be formulated based on literature review: research questions should be written according to what direction any previous research leads you
- Examples of broad clinical research questions (From Vanderbilt School of Nursing):
  1. Does the administration of pain medication at time of surgical incision reduce the need for pain medication twenty-four hours after surgery?
  2. Which maternal factors are associated with obesity in toddlers?
  3. What elements of a peer support intervention prevent suicide in high school females?

- Depending on the research the question may be very exact or broader
- Usually the ethical permissions require research questions to be set before the study
- Studies of clinical care might have broader questions than testing a certain drug or device

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Probability Theory in Research

- **Probability theory** is defined as a model for demonstrating or predicting events or phenomenon under conditions of uncertainty
- It is a fundamental tool used by researchers, health-care providers, insurance companies, and many others to make decisions in contexts of uncertainty
- In health care, probability theory can be used to understand the relationship between exposures and the risk of health effects
- Probability theory application depends on the outcome or event happening over a large number of repetitions, or with a large number of people

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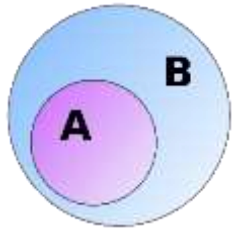
Probability Theory Explained



- **Probability** provides information about the likelihood that a defined event will occur
- It is quantified as a positive number between 0 (the event is impossible) and 1 (the event is certain)
- The higher the probability of a given event, the more likely it is to occur
- Example: If A is a defined event, then the probability of A occurring is expressed as P(A)
- Given two events A and B, we often want to determine the probability of either event, or both events, occurring.
- The *addition rule* is used to determine the probability of at least one of two (or more) events occurring. In general, the probability of either event A or B is given by:
  - P(A or B) = P(A) + P(B) – P(A and B)

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Probability Theory Explained (cont'd)

- If A and B are *mutually exclusive*, this means they cannot occur together, i.e. P(A and B)=0. Therefore, for mutually exclusive events the probability of either A or B occurring is given by:
  - P(A or B) = P(A) + P(B)
  - *Example: If event A is that a person has blood type O and event B is that they have blood type B, then these events are mutually exclusive, since a person may have only one or the other.*
    - *Therefore, the probability that a given person has either type O or B is P(A)+P(B).*

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Probability Theory Explained (cont'd)

- The *multiplication rule* gives the probability that two (or more) events happen together. In general, the probability of both events A and B occurring is given by:
  - P(A and B) = P(A) x P(B/A) = P(B) x P(A/B)
- The notation P(B/A) is the probability that event B occurs *given that* event A has occurred where the symbol '|' is read as 'given'. This is an example of a *conditional probability*, the condition being that event A has happened.
  - For example, the probability of drawing the ace of spades from a well shuffled pack is 1/52. The probability of the ace of spades given that the card is black is 1/26.
  - *Example: If event A is a person getting neuropathy and event B is that they are diabetic, then P(A|B) is the probability of getting neuropathy given that they are diabetic.*

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Probability Theory Explained (cont'd)

- If A and B are *independent events*, then the probability of event B is unaffected by the probability of event A (and vice versa). In other words, P(B|A) = P(B).
- Therefore, for independent events, the probability of both events A and B occurring is given by P(A and B) = P(A) x P(B).
  - *Example: If event A is that a person has blood type O and event B that they are diabetic, then the probability of someone having blood type O and being diabetic is P(A) x P(B), assuming that getting diabetes is unrelated to a person's blood type.*
- Note that if A and B are *mutually exclusive*, then P(A|B)=0

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Probability Theory Explained (cont'd)

- Probability can be expressed in a number of ways:
  - A *frequentist* approach involves observing a number of particular events out of a total number of events. Thus, we might say the probability of a boy is 0.52, because out of a large number of singleton births we observe 52% are boys.
  - A *model* based approach is where a model, or mechanism determines the event. Thus, the probability of a '1' from an unbiased die is 1/6 since there are 6 possibilities, each equally likely and all adding to one.
  - An *opinion* based approach is where we use our past experience to predict a future event. Thus, we might give the probability of a specific football team winning the next match, or whether it will rain tomorrow.

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The Application of Probability Theory in Health IT Research

- The applicability of probability theory in IT supported health research can foster better patient care and robust outcomes
- Probability is an important theory in health IT and can be used to determine how great the risks of getting a disease or how common some conditions are
- For example, for every diagnostic procedure (which may involve a laboratory test of a sample taken) there is a set of fundamental questions that should be asked that involve probability
  - Firstly, if the disease is present, what is the probability that the test result will be positive? This leads to the notion of the sensitivity of the test.
  - Secondly, if the disease is absent, what is the probability that the test result will be negative? This question refers to the specificity of the test.

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The Application of Probability Theory in Health IT Research (cont'd)

- Probability can help determine which test to use if it is known what the 'true' diagnosis is
  - In the case of heart disease, test options could include a relatively inexpensive EKG, echocardiogram, treadmill or, for example, an expensive and risky procedure such as angiography
  - In other situations it may help to have an "expert" opinion
  - Probability coupled with known diagnoses enhance the ability to best utilize the so-called **gold standard**: the benchmark, or best available test under reasonable conditions and without restrictions
- Example of a health issue related to probability:
  - Cystic fibrosis (CF): If both of the parents are carriers of the gene, there is a 1 to 4 (25%) chance that their child will have cystic fibrosis
  - Although this probability exists, it is not CERTAIN that parents who carry the CF gene will have one child in four with CF, although it is very likely

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Elements of Healthcare Data for Research Purposes

- Major sources of healthcare data include previously collected data. Pros and cons of previously collected healthcare datasets: Con: Because someone else has collected the data, they do not know what purpose future users are using it for, so the data may not be as useful. Pro: Getting a ready made data saves resources and data may have been more widely collected than current users can collect.
- Healthcare data sets include:
  - *Administrative data* with the use of services
  - Patient medical records including *EHRs/EMRs* of patients' health with their consent
  - *Patient surveys*
  - *Open-source datasets* for others to do research including de-identified data collected specifically for other researchers to use

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Elements of Healthcare Data for Research Purposes (cont'd)

- **Requestors:** are the person(s) requesting healthcare data for their research
- **Users:** Can be individual clinicians, such as nurses, physicians, clinical investigators, drug manufacturers, researchers, or part of research teams and organizations (PhD students, post-doctoral researchers, professors, etc.)
- **Uses**: Users are using the research data to provide more general information about a certain phenomenon, or try to answer to a specific research question to improve healthcare

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Primary, Secondary and Tertiary Research

Primary Research

- **Primary research** is written by the researcher who conducted the study, e.g., a research article. Primary research sources are original materials/information on which other research is based. It includes journal articles of original research, conference papers, dissertations, technical reports, and patents. Primary sources are also sets of data, such as health statistics, which have been tabulated, but not interpreted.

Secondary research

- **Secondary research** is based on studies that are conducted by someone other than the writer of the secondary research, e.g., a review article of a research project. Secondary sources analyses, evaluates, interprets, re-packages, summarizes or reorganizes information reported by researchers in the primary literature.

Tertiary research

- **Tertiary research** consists of reports and studies that have been compiled, analysed and disseminated by others. Tertiary sources consist of primary and secondary source information which has been collected and distilled. They present summaries of or an introduction to the current state of research on a topic, summarize or condense information from primary and secondary sources, or provide a list of primary and secondary sources of more extensive information.

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Best Practices in Healthcare Research

Best practices in healthcare research often incorporate techniques that utilize health IT/eHealth tools.

Key principles of Good Health Research Practices (GHRP) include the following. eHealth components are identified in parentheses.

1. **Ensuring ethics and quality underpin all types of research** involving human participants (using ethics and quality components of eHealth information and systems)
2. **Assessing risk** prior to and during the course of research, with appropriate mitigation measures put in place (utilizing eHealth when possible)
3. **Providing informed consent** that is appropriate for the study and in accordance with the cultural context of the study site (utilizing eHealth when possible)

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Best Practices in Healthcare Research (cont'd)

4. **Writing effective procedures** in line with the study protocol to ensure the consistency and conformance of activities (digital documentation used via eHealth)
5. **Qualifying staff** through appropriate training, education, and experience, which will ensure they undertake roles in line with their qualification (eHealth skills, training and proficiency determination)
6. **Quality assurance in planning and monitoring of study activities** is important to assure the process and data quality (utilizing eHealth when possible)
7. **Duly protecting privacy** of the research participants and the confidentiality of all data acquired during the study (privacy features incorporating GDPR, HIPAA, etc.)
8. **Making research results and reports publicly available** (utilizing eHealth when possible)

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Validation and Verification Principles for Health Data Research Using eHealth

- The process of verification and validation of research is ideally and most effectively applied throughout the entire research process
- *Verification* is the evaluation of the process and results to ensure that they satisfy the specific requirements used to define the design of the study or research
- *Validation* is the evaluation of the process and results to ensure they satisfy external criteria of accuracy or correctness, e.g., the end-user or specific requirements that are intended to be realized upon implementation and execution of the research, or benchmarked upon literature review

validation verification

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Validation and Verification Principles for Health Data Research Using eHealth (Cont'd)

- Data validation is needed to ensure that collected health information data is complete, reliable, accurate and comparable
- For example if a dataset is collected whether a person has diabetes or not, at least following things should be noted:
  - Does the person have type 1 or type 2 diabetes?
  - Is the assumption that "50 year-old European females have more diabetes" based on the fact that more of them really have diabetes, or was this demographic more willing to participate in the study, and thus the number of participants in this group is also higher?
  - Are the groups (diabetes, no diabetes) similar enough, e.g., do they have similar age or sex distribution
- Verification ensures that data is fulfilling the specified requirements

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Basic Principles of Biomedicine

- **Biomedicine**, also called medical biology, is a branch of medical science that applies biological and physiological principles to clinical practice
- Biomedicine can also relate to many other categories in health and biological related fields.
- It includes many biomedical disciplines and areas of specialty that typically contain the "bio-" prefix such as:
  - molecular biology, biochemistry, biotechnology, cell biology, and embryology
  - nanobiotechnology, biological engineering, and laboratory medical biology
  - cytogenetics, genetics, and gene therapy
  - bioinformatics, biostatistics, systems biology, and neuroscience
  - microbiology, virology, immunology, and parasitology
  - physiology, pathology, and anatomy
  - toxicology, and many others that generally concern life sciences as applied to medicine

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Basic Principles of Biomedicine (cont'd)

- Biomedicine involves the study of (patho-) physiological processes with methods from biology and physiology. These processes are studied with the particular point of view of devising new strategies for diagnosis and therapy.
- Depending on the severity of the disease, biomedicine pinpoints a problem within a patient and fixes the problem through medical intervention

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The Use of eHealth in Biomedicine

- Informatics methodologies utilize computer-assisted techniques to help biomedical researchers manage large amounts of information
- Data mining techniques offer assistance in research by identifying biomedical entities (e.g., genes, substances, and diseases) and showing relationships between them in the data
- An informatics method called “discovery browsing” provides a principled way of navigating through selected aspects of biomedical research areas
  - The method supports an iterative process that accommodates learning and hypothesis formation in which a user is provided with high level connections before delving into details

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Unit Review Checklist

- ❑ Described eHealth research and stated its importance
- ❑ Described the research process, including citing resources, tracking work, and referencing or repeating the process if and when needed, using health IT/eHealth tools when available (CCB14)
- ❑ Conveyed the importance of developing precise and relevant questions for research (CCB05)
- ❑ Described probability theory and the applicability of probability theory in IT supported health research to foster better patient care and robust outcomes (CCB09)

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Unit Review Checklist (cont'd)

- ❑ Identified various requestors, major sources, uses and users of health care data for research purposes (CCB04)
- ❑ Differentiated between primary and secondary research (CCB02)
- ❑ Named eight best practices in healthcare research techniques that utilize health IT/eHealth tools (CCB10)
- ❑ Stated the validation and verification principles for research data and information using health IT/eHealth (CCB15)
- ❑ Explained the basic principles of biomedicine (CCB17)
- ❑ Described the use of eHealth in biomedicine (CCB11)

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Unit Review Exercise/Activity

1. Name the nine components of the research process.
2. Research the publication entitled, “Prevalence and incidence of Alzheimer's disease in Europe: A meta-analysis” by Niu H, Álvarez-Álvarez I, Guillén-Grima F, and Aguinaga-Ontoso I.
   a. What source can you cite for your research (where did you find the article referenced)?
   b. Who originally published the article?
   c. What is the main background/finding of the article?
   d. From reading the article, would the information be considered primary or secondary/tertiary research?
3. What is the difference between primary and secondary research?
4. What are the three approaches in which probability theory can be explained?

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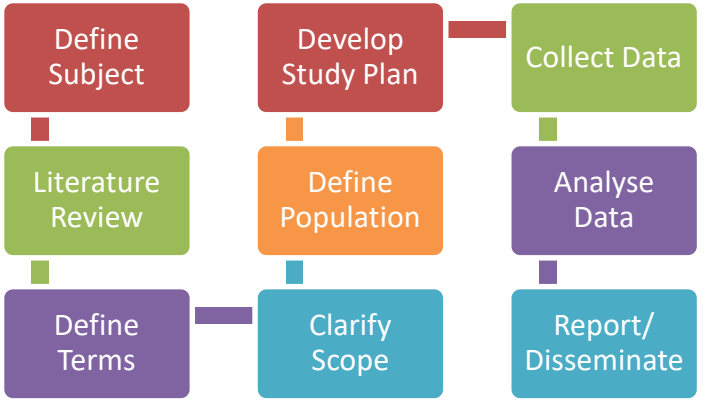
Unit Exam

1. *Citing resources* is an important part of which step of the research process?
   a) Define subject
   b) Literature review
   c) Clarify scope
   d) Analyse data



2. *Determining what data will be collected* is part of which step?
   a) Develop Study Plan
   b) Collect Data
   c) Analyse Data
   d) Report/Disseminate

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Unit Exam (cont'd)

3. P(B/A) = P(B) reflects which probability theory?
   a) If A is a defined event, it describes the probability of A occurring
   b) The probability of either event A or B occurring
   c) A and B are mutually exclusive
   d) The probability of both events A and B occurring
4. "Reports and studies that have been compiled, analysed and disseminated by others" best describes:
   a) Primary data
   b) Secondary data
   c) Secondary research
   d) Tertiary research

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Unit Exam (cont'd)

5. eHealth skills, training and proficiency determination is part of which Good Health Research Practice (GHRP)?
   a) Ensuring ethics and quality underpin research
   b) Providing informed consent
   c) Qualifying staff
   d) Duly protecting privacy
6. "A principled way of navigating through selected aspects of biomedical research areas" describes which concept?
   a) discovery browsing
   b) data mining
   c) verification
   d) validation

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