UTSA CS 4593: CS-CURE

Course-based Undergraduate Research Experience in CS

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Week 8: **Research Methodologies**

UTSA CS-CURE

Week 8

- Objectives:
    - Identify key components of a research proposal
    - Identify research methods most useful to a chosen research problem
    - Design & outline a research study in a chosen field

- Deliverables:
    - Activity 6 worksheet (*in-class Thursday*)
    - SIG Meeting 2 (*in-class Thursday)*
    - Research Outline - *due Saturday*

Research Methodology

Computer Science Research

Designs & Methods

Research Design

a comprehensive **plan**
outlining the framework for
conducting research
in order to answer
a specific research question

Research Methodologies

specific **techniques & tools**
used to collect, measure,
and analyze data
in a research project

This week!

Computer Science Research

analogy: constructing a building

Research Design

Research Methodologies

Research Methodology

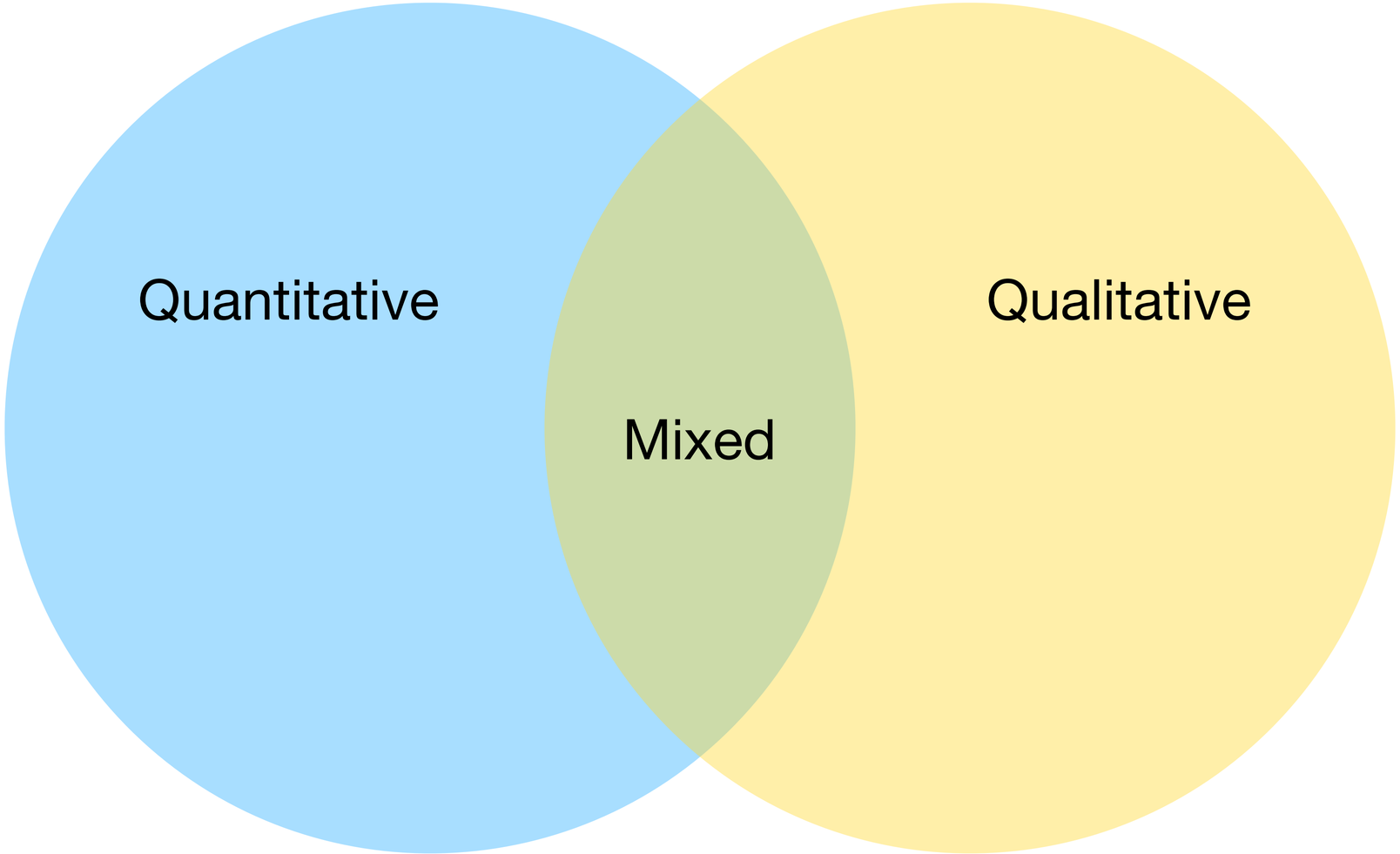
Specific techniques, strategies, & tools

- **Methodology** = strategies & tools you'll use to answer research questions.
    - Justifies the validity of your research work.

- Examples: surveys, experiments, data analysis, & more..

Research Methodology

Method types



Quantitative Methods

Quantitative Research

Research Methodologies

Focuses on **numerical data collection & analysis using statistical methods**.

- *Pros: objective data, allows for generalization, facilitates hypothesis testing.*
- *Cons: may overlook the complexity of human behavior, and/or miss details.*

Survey

Correlation

Experiment

Survey Research

Quantitative Research Methods

- This method involves collecting data from a large group of people using questionnaires or surveys.

- Example:
    - Survey research on customer satisfaction with a new product.

Correlational Research

Quantitative Research Methods

- This method investigates the relationships between variables without manipulating them.

- Example:
    - Correlational research on the relationship between exercise and mental health.

Experimental Research

Quantitative Research Methods

- This method involves manipulating one or more variables and observing the effect on another variable.

- Example:
    - Experimental research on the effectiveness of a new drug treatment.

Qualitative Methods

Qualitative Research

Research Methodologies

Explores & understands phenomena through non-numerical data (e.g. interviews, observations).

- *Pros: in-depth understanding, rich description of experiences, captures details*
- *Cons: subjective data, limited generalizability, relies on interpretation*

Case Study

Ethnographic

Phenomenological

Case Study Research

Qualitative Methods

- This method involves in-depth investigation of a single individual, group, or event.

- Example:
    - Case study research on a child with AATD (alpha-1-antitrypsin deficiency)

Ethnographic Research

Qualitative Methods

- This method involves studying a culture or group of people by immersing oneself in their world.

- Example:
    - Ethnographic research on the culture of a street gang.

Phenomenological Research

Qualitative Methods

- This method explores the lived experiences of individuals from their own perspectives.

- Example:
    - Phenomenological research on the experiences of patients with chronic pain.

Mixed Methods

Mixed Methods

Research Methodologies

Combines quantitative & qualitative methods within a single study.

- *Pros:*
  - *provides a comprehensive understanding of a phenomenon*
  - *addresses limitations of the single methods*
- *Cons:*
  - *Increased complexity*
  - *Potential for data integration challenges*

Examples

Example: **Systems**

- **Research Question(s):**
    - How can cloud computing architectures be optimized to efficiently manage and deliver streaming media content to a geographically distributed user base with minimal latency and high quality of service?

- **Methodology (Quantitative)**:
    1. Develop and simulate different cloud computing architecture models to evaluate their performance in terms of resource utilization, data transfer efficiency, and overall latency for streaming media delivery.
    2. Analyze the results to identify the most efficient and scalable architecture for the given scenario.

Example: **AI Applications**

- **Research Question(s):**
    - Can AI-powered chatbots effectively provide customer support services?
    - What factors contribute to user satisfaction and adoption of such systems?

- **Methodology (Mixed)**:
    1. **Quantitative:** Develop and implement an AI-powered chatbot to handle customer service inquiries on a specific platform.
    2. Collect and analyze user data (e.g., interaction transcripts, satisfaction surveys) to evaluate the chatbot's effectiveness in addressing queries and resolving customer issues.
    3. **Qualitative:** Conduct focus groups or user interviews to gain qualitative insights into user experiences and preferences regarding interaction with AI-powered chatbots in customer service settings.

Example: **Cybersecurity**

- **Research Question(s):**
    - How effective are different multi-factor authentication (MFA) methods in preventing unauthorized access to corporate networks?
    - What are the usability trade-offs associated with each method?

- **Methodology (Mixed)**:
    1. **Quantitative:** Conduct a survey among employees to assess their usage patterns and perceptions of different MFA methods.
    2. Analyze the survey data to determine user preferences and identify any usability challenges.
    3. **Qualitative:** Conduct interviews with security professionals and a select group of employees to gain deeper insights into the user experience, adoption challenges, and overall effectiveness of specific MFA methods.

Example: **Quantum Computing**

- **Research Question(s):**
    - How can quantum algorithms like Grover's Search be applied to accelerate the process of drug discovery by efficiently searching through vast chemical databases?

- **Methodology (Exploratory)**:
    1. Review existing literature on quantum algorithms and their potential applications in drug discovery.
    2. Conduct theoretical simulations to explore the potential benefits of using quantum algorithms for specific tasks, such as identifying candidate molecules with desired properties.

Example: **Algorithms**

- **Research Question(s):**
    - How can we design efficient and scalable graph algorithms to analyze large social networks?
    - How do performance and scalability vary across different algorithm implementations for this task?

- **Methodology (Quantitative)**:
    1. Implement and compare different graph algorithms for analyzing large social network datasets (e.g., community detection, centrality measures).
    2. Evaluate the performance of each algorithm in terms of efficiency (time complexity) and scalability (ability to handle increasing data size) on a high-performance computing platform.

Example: **Data Science**

- **Research Question(s):**
    - Can machine learning algorithms be used to predict the risk of credit card fraud with high accuracy?
    - How can we balance this objective with protecting the privacy of customer data?

- **Methodology (Quantitative)**:
    1. Utilize historical data on credit card transactions, including fraudulent activities, to train a machine learning model for fraud prediction.
    2. Evaluate the model's performance and assess its trade-off between accuracy and potential privacy risks associated with data collection and analysis.

Example: **AI Ethics**

- **Research Question(s):**
    - How can we ensure fairness and transparency in AI-powered decision-making systems, particularly when applied to high-stakes domains like loan approvals or criminal justice?

- **Methodology (Qualitative)**:
    1. Conduct in-depth interviews with experts in AI ethics, legal professionals, and stakeholders affected by AI-based decision-making systems.
    2. Analyze interview data to identify key ethical concerns, potential biases in existing systems, and explore potential solutions and best practices for promoting fairness and transparency in AI development and deployment.

Example: **Computer Vision**

- **Research Question(s):**
    - Can deep learning algorithms be used to automate the detection of early signs of diabetic retinopathy in retinal fundus images?
    - How does their performance compare to traditional screening methods employed by ophthalmologists?

- **Methodology (Quantitative)**:
    1. Develop and train a deep learning model using a large dataset of labeled retinal images with and without diabetic retinopathy.
    2. Evaluate the model's performance on a separate test dataset and compare its accuracy and sensitivity to traditional screening methods.

Types of Research

Research Designs

Design	Description
Action Research	Conducted by practitioners or educators within their own context to solve practical problems. It focuses on improving practices and outcomes.
Case Study	Involves in-depth examination of a single case or a few cases. They are valuable for exploring complex and unique phenomena.
Correlational	Investigates the relationship between two or more variables without manipulation. It assesses the strength and direction of associations but does not establish causation.
Cross-Sectional	Gathers data from subjects at a single point in time. It's suitable for comparing different groups or variables at a specific moment.
Descriptive	Aims to describe and document the characteristics, behaviors, or phenomena under study without altering them. Surveys, observations, and case studies are common methods in descriptive research.
Ethnographic	Involves immersion in a particular culture, group, or community to gain an in-depth understanding of their practices, beliefs, and behaviors.
Experimental	Involves manipulating one or more variables to observe their effect on another variable while controlling for extraneous factors. It is characterized by random assignment to experimental and control groups.
Quasi-Experimental	Shares similarities with experimental design but lacks random assignment. Researchers often use existing groups or conditions, making it suitable for certain practical situations.
Exploratory Research	Conducted when little is known about a topic. It aims to generate hypotheses and provide initial insights.
Ex Post Facto	Examines the effects of independent variables that cannot be manipulated directly (e.g., gender, age) by comparing groups that already differ on these variables.
Longitudinal	Involves studying the same subjects or groups over an extended period to observe changes or trends over time. It's often used to study developmental or longitudinal effects.
Meta-Analysis	Involves the statistical synthesis of results from multiple studies to draw overarching conclusions about a particular research question.
Mixed-Methods	Combines qualitative and quantitative research methods within a single study to provide a more comprehensive understanding of a research problem.
Survey	Collects data from a sample of individuals through structured questionnaires or interviews. It's useful for gathering opinions, attitudes, and preferences.

Research Proposals - Supporting your research goals

Research Proposals

Supporting your research goals

- Proposals consist of a **design plan** and **methodologies.**
    - Design: what do you want to do and why?
    - Methods: how will you do it and what do you need?

- *If you can't specify both of these, it won't be successful.*

Research Proposals

Key components

1. Research Question(s) - *what do you want to do?*
2. Motivation - *why?*
3. Methods - *how will you do this?*
    - Tools/approaches, datasets, evaluation metrics, specific technologies
    - Timeline with milestones/deliverables
4. Budget - *how much will it cost?*
    - Resources - *what do you need? Who will do the work?*

Research Proposals

Resources & Planning

- Break down the research into 2-4 main tasks.

- What equipment or materials are needed?
- Who will perform the work?
- When & where?

Example timeline for research proposal planning.

Year	1												2												3												4							
	2021				2022												2023												2024												2025							
Month	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8
Task 1	*Adversarial Patch Attacks*																																													
1.A																																														
1.B																																														
1.C																					*																								
1.D																																	*												
Task 2	*Gradient-free Adversarial Examples*																																													
2.A																																														
2.B																																														
2.C																					*																								
2.D																																						*								
Task 3	*Transferability & Defenses*																																													
3.A																																														
3.B																																														
PI																																														
GRA																																														
URE																																														

Research Proposals

Budget Components

- How will researchers be involved and compensated?
    - Will they have benefits?
    - If students, will you cover their tuition?
- If you have human participants, will they be compensated?
    - Do you need IRB approval?
- What equipment or materials do you need to buy?
- For publishing your findings: What publication costs or travel expenses will there be?

Wrap-Up

Tuesday

- Identify key components of a research proposal
- Identify research methods most useful to a chosen research problem
- Design & outline a research study in a chosen field

- <u>To Do</u>:
    - Activity 6 worksheet (*in-class Thursday*)
    - SIG Meeting 2 (*in-class Thursday)*
    - Research Outline - *due Saturday*

See you Thursday!

Activity 6:
Research Methodologies

Activity 6: **Research Methodologies**

Designing effective research studies

- Identify a research method relevant to your research project
- Scope resources needed, set up a timeline with tasks
- Approximate a budget for the research

Activity 6: **Research Methodologies**

Designing effective research studies

- Handout: **Planning Your Research**
    - *Activity*: reflect on what you would need in order to execute your research project
    - *Goal*: clarify specific research tasks by envisioning the “who, what, where, when”

Activity 6: Planning Your Research

Personnel

Role	Hourly Pay	# of hours per week	# of weeks per year	# of years on project	Total Cost
PI					
GRA					
URA					
URE					

URA = 10-15 hours per week in the academic year (Fall & Spring 16 week semesters) and up to 40hrs per week in summer (8-10 weeks).

$

Participant Support

Number of human subjects:

Payment per participant:

Scholarships:

$

Equipment

Number of Items greater than $5k:

Cost:

$

Tuition & Fees

Cost of graduate tuition & fees: $15,500

Number of students:

Number of years on project:

$

Materials

Items less than $5k:

Publication fees:

Food / facilities:

Number of years on project:

$

Travel

Cost per trip
= airfare + hotel + food + registration

Example 4 day trip:
= 600 + (200x4) + (75x4) + 600 = $2,300

Cost per trip:

Number of travelers:

Number of trips:

$

Total Budget Calculation

F&A Included

Sum all of the yellow totals (personnel, materials, travel), then multiply by 1.5

F&A Excluded

Sum all of the green totals (participants, equipment, tuition/fees)

Project Total: Sum of the above 2 calculations

$

Instructions:

As you develop a research proposal, consider *how* you would accomplish each task. What would you need in order to execute each phase? Do you need equipment or access to data? Who will perform the research? Where will you disseminate your results? Do you need to travel there? As you answer these questions, iteratively update your budget to include all costs. Once you have filled the green and yellow boxes, do a final calculation of your project total in the blue box.

SIG Meeting 2:
Evaluating Research

SIG Meeting 2: **Evaluating Research**

Providing peer feedback

- Exchange research proposals with a SIG peer
    - Would *you* fund this research?
    - What would you do differently?

Wrap-Up

Thursday

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See you next week!