

Introduction to AI Research Methods

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Designed as a quick-reference guide for students and newcomers to the field.

1. Why Study Research Methods in AI?

Goal	What It Enables
Reproducibility	Others can verify and build on your work.
Validity	Demonstrate that results truly reflect the phenomenon being studied.
Efficiency	Choose the right tools and avoid duplicated effort.
Ethical Responsibility	Anticipate bias, privacy, and societal impact.

2. The AI Research Lifecycle

Problem Definition ? Literature Review ? Hypothesis/Formulation ?
Data Acquisition ? Model Development ? Evaluation ?
Analysis & Interpretation ? Publication ? Reproducibility Checks

Each stage has its own methodological toolbox (see sections below).

3. Core Research Paradigms

Paradigm	Typical Questions	Common Techniques
Theoretical / Algorithmic	<i>Can we prove convergence? What is the computational complexity?</i>	Formal proofs, complexity analysis, asymptotic bounds.
Empirical / Experimental	<i>Does this architecture outperform baselines on benchmark X?</i>	Controlled experiments, ablation studies, statistical testing.
Applied / Engineering	<i>How does the system behave in a real world deployment?</i>	Field trials, A/B testing, user studies.
Interdisciplinary / Societal	<i>What are the fairness implications of model Y?</i>	Survey methods, qualitative analysis, impact assessment.

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4. Designing an Experiment

1. Define Variables

- *Independent*: model architecture, hyperparameters, data preprocessing.
- *Dependent*: accuracy, F1, latency, energy consumption, user satisfaction.

2. Select a Baseline

- Choose a strong, widely-cited reference (e.g., BERT for NLP, ResNet-50 for vision).

3. Control Confounders

- Fix random seeds, hardware, training budget, and data splits.

4. Determine Sample Size

- Use power analysis or pilot studies to estimate the number of runs needed for statistical significance.

5. Specify Evaluation Metrics

- Align metrics with the research question (e.g., ROC-AUC for imbalanced classification).

6. Plan Reproducibility

- Store code (Git), data versioning (DVC, Git-LFS), and environment specifications (Docker, Conda).

5. Data-Centric Methods

Aspect	Best Practices
Acquisition	Open datasets (e.g., ImageNet, GLUE), web scraping with ethical compliance, synthetic data generation.
Cleaning & Pre-processing	Missing-value handling, outlier detection, normalization, tokenization, data augmentation.

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Aspect	Best Practices
Splitting	Train / validation / test (commonly 70/15/15) or cross-validation for small datasets.
Label Quality	Crowdsourcing with gold standard checks, inter-annotator agreement (Cohen's κ).
Bias Auditing	Demographic parity checks, subgroup performance analysis, counterfactual testing.

6. Model Development Strategies

Strategy	When to Use	Key Steps
Baseline/First	Early-stage projects	Implement a simple model (e.g., logistic regression) to set a performance floor.
Incremental Complexity	Controlled ablations	Add one component at